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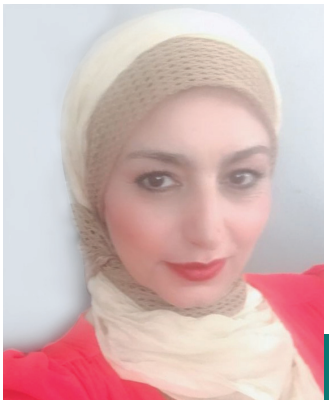

Supply chain management and optimization in transportation logistics

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Editorial

Supply chain management (SCM) is the decision-making process that steers numerous activities in order to generate added values for all stakeholders. The aim of this process is to optimize each activity in terms of advantageous profits to the suppliers, retailers and customers. In addition, the efficient planning of activities can be profitable for product development, sourcing, logistics and all flows that can link those activities. SCM can also be seen as the process of optimizing a set of decisions that generate cost-effective solutions which provide efficient plans for acting on numerous levels while considering all decision-making standpoints. SCM can therefore be defined as the set of activities utilized to efficiently integrate the different elements of the SC so that products are produced and distributed at the right quantities, to the right locations and at the right time, in order to maximize system, gain while satisfying service-level requirements.

One of the most effective activities in the SC is the transportation and delivery of products to traders and end users. As this activity impacts all stakeholders, it has a direct effect on the pricing policy of the final products.

In the area of SCM, transportation problems are related to determining optimal routes for vehicles going from one or more distribution centers to a set of customers' locations. These problems are known as vehicle routing problems and have a fundamental economic importance in the field of distribution and customers' satisfaction. The main objective of transportation logistics is to deliver predefined demands to a set of customers while minimizing the transportation costs. Alternatively, the transportation logistics can be viewed as finding the set of routes for a predefined set of vehicles while satisfying all customers' requirements. By involving additional constraints on routes' construction, various types of transportation logistics problems are stated.

Today's complex global supply chains are full of uncertainty. The volatile economic environment and customers' demands variability require supply chains to be able to anticipate, control and react to disruptions and volatility, in collaboration with customers, suppliers and logistics partners. In order to restore SC stability, companies are looking for ways to optimize their global SC operations and execute on a customer value strategy of selling and fulfilling the right products and services at the right price, place and time. Transportation is one of these world players that have a daily struggle to offer their customers not only the best products but also the best experience, at the right time, price and quality. The main purpose in the delivery activity is to optimize the transfers between all sites that can produce different varieties of items and make sure they are available in the right quantities demanded at the right point of sale. Traditionally, two alternative objectives are considered:

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the minimization of the total distance traveled or the minimization of the total travel cost. This minimization is subject to system constraint as the route continuity, the delivery to each customer once and the fulfillment of trucks' capacity limitations. The delivery problem thereby specified gives rise to a routing solution that uses a subset of the available trucks while detailing each truck's pathway.

To sum-up the above discussion, we can say that the delivery in the SC consists of specifying:

- *A warehouse that constitutes a procurement source for customers' orders.*
- *A set of customers to be served, their locations, their demands and the tie windows for the delivery of their orders.*
- *A set of available trucks to be used for the delivery of orders.*

Hence, given such input data, the transportation logistics consists of minimizing the travel cost of the set of trucks used for the delivery process, while fulfilling routing constraints. Hence, the delivery in the SC can be formally modelled as an optimization problem which is a formal specification of a set of proposals related to a specific framework that includes one decision maker, one or several objectives to be reached and a set of structural constraints. Optimization has been practiced in numerous fields of study as it provides a primary tool for modeling and solving complex and hard constrained problems. Throughout the 1960s, exact and approximate approaches received considerable attention as useful tools in solving optimization problems. Depending on the problem structure and its complexity, appropriate solution approaches were proposed to generate high quality solutions in a reasonable computation time. Several optimization studies were designed in such a way to find the best solution, which corresponds to the optimal value of a single objective function. The challenge of solving combinatorial problems lies in their computational complexity since most of them are hard constrained. This complexity can mainly be expressed in terms of the relationship between the search space and the difficulty to find a solution. The search space in combinatorial optimization problems is discrete and multidimensional. The dimensionality of the search space greatly influences the complexity of the decision problem.

A decision-making problem is the quantitative modeling of a problem situation. Generally speaking, a decision-making problem is split into the following three main components:

- *The decision maker(s).*
- *The objective(s) to be reached.*
- *The set of structural constraints that bound the feasible set.*

Depending on these components, we can point out the solution approaches that solve a decision-making problem. To do so, it is required for the decision maker to study the problem complexity in order to identify the class to which the decision problem lies. We can point out two main solution approaches for a decision problem: the optimization and the game theory approach. For the optimization modeling, two main classes of decision-making problems are:

1) *Constrained decision problems modeled as the optimization of an objective expressed while fulfilling a set of structural constraints that bound the decision space. In such case, the problem is designed in terms of two components: the objective and the set of constraints.*

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2) *Unconstrained decision problems that consist of minimizing or maximizing a function. The main concern is the finding of the solution value that corresponds to the global optimum. In this case, there is neither consideration of system constraints nor the range of the solution.*

Generally, the inputs and outputs (after optimization) are to be specified in order to well express the needs and the calibration of an optimization problem. For this reason, we choose, in the current part, to classify broadly solution approaches into two major categories which are exact and approximate methods.

- *Exact methods that guarantee the convergence to an optimal solution for the transportation problem. As this problem is hard, only small sized instances can be solved using an exact method.*
- *Approximate methods as heuristics and meta-heuristics, are techniques that solve problems in a reasonable runtime and memory consumption, compared to exact algorithms. But, it no guarantees the optimality of the generated solution. These methods are typically used for solving real life problems because of their speed and their ability to handle large instances. In the class of approximate methods, we point out heuristic and meta-heuristic approaches. For transportation logistics, the most used approaches are the approximate methods since the problem is very complex to solve.*

Transportation is an important activity in the SC as it influences the whole process in terms of cost and quality of service. An introductory scheme pointed out for the delivery in the supply chain. Then, we stated some basics of the transportation as an optimization problem. As the transportation activity is a hard optimization problem, two solution approaches are to be considered: exact and approximate methods. These two classes can scan all problem sizes while generating optima and near optimal solution. As potential perspectives, we can study the importance of implementing a decision support system for a right management of transportation logistics within the supply chain.

BIOGRAPHY

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A Multi-band MIMO Antenna System with Coupled-fed Modified Rectangular Patch Elements for 5G Systems

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ABSTRACT

A four-port multiple input multiple output (MIMO) antenna system constructed of four compact dual-band (38/60 GHz) microstrip patch antennas is proposed for 5G mobile applications. Each individual element is optimized to achieve the desired performance of the overall MIMO system. Numerical and experimental investigations are achieved to assess the performance of both the single-element antenna and the four-port MIMO antenna system. It is shown that the simulation results agree with the experimental measurements, and both show good performance of the proposed MIMO antenna system. The bandwidths achieved around 38 GHz and 60 GHz are about 2 GHz and 3.2 GHz, respectively. The performance of the MIMO antenna system including the return loss at each antenna port and the coupling coefficients between the different ports are investigated. The radiation patterns produced when each port is excited alone are shown to be suitable for spatial diversity scheme. They have a high radiation efficiency exhibited by a balloon-like shaped radiation pattern for both the upper and lower frequency bands. It is shown that the envelope correlation coefficient (ECC) and the diversity gain (DG) are suitable for performance for the targeted 5G bands.

Index Terms: MIMO, dual-band, 5G mobile, mobile terminal, microstrip patch antenna, antenna design, diversity.

1. INTRODUCTION

The need for endless users joining the network with high rates of information being sent and received has been the driving force behind the boom of the auspicious Fifth-Generation (5G) technology [1]. The data rates have massively exploded to reach 100 times nowadays and as expected, 1000 times by 2030 [2]. Multi-input-multi-output (MIMO) techniques play an important role in increasing the wireless channel capacity by deploying multiple antennas at the transmitter and the receiver without the need for additional power or spectrum [3-5]. Diversity schemes are considered to be a key component to combat fading and enhance the wireless link reliability by sending the same signals by uncorrelated antennas.

The abandoned Millimeter-wave spectrum (30-300 GHz) wave is anticipated to be a dominant factor due to its multi-Gigabit/s transmission rate possessing the wide available bandwidth to fulfil the demands of the proliferation of 5G applications which require high quality and low latency transmission [6-9]. The Federal Communications Commission (FCC) has allocated the bands of 59-64 GHz for high

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speed wireless communications and short range as an unlicensed band [10]. The International Telecommunications Union (ITU) has allocated the frequency bands which are centered at 28, 38, 60 and 73 GHz for 5G mobile communications [11]. Mobile phones are restricted by a very limited space which highlights a difficult challenge to integrate several antenna elements with high isolation which is a vital necessity for a MIMO antenna system with a good performance [12-15]. The proposed dual-band MIMO antenna in the present work utilizes the 38-GHz frequency band (potential candidate for next generation communication) and the 60-GHz frequency in a single compact antenna to be properly allocated to achieve excellent isolations between all elements.

Recently, many designs for mobile handset antennas for 5G applications are provided. In the work of [16], the MIMO antenna system operate in the 28 and 38 GHz bands by two ports which are realized by two antenna arrays. The work of [17] is concerned with the dual band (28/38 GHz) which gives the duality by the main radiator being etched by an inverted U-shaped slot. The work of [18] adopts three stacked patches to work in the dual band (28/38 GHz). In [19], a MIMO antenna system is designed to serve the fourth generation (4G) with a bandwidth of 2 GHz and 5G bands of (28, 37 and 39 GHz) on a single antenna. Each element in the system consists of a slot-based antenna and is fed by two microstrip feeders. The work of [20] investigates a 60 GHz array of antennas which are composed of feedlines, ground and parasitic elements. As specified in [21], the isolation between the meander-line dual-band antennas is achieved by a split electromagnetic band gap structure where the antenna is coupled to a parasitic patch to achieve the duality of bands. The splits applied are to decouple at the first resonant mode and utilize the Electromagnetic Band Gap (EBG) to decouple at the second resonant mode. The work of [22] presents a compact antenna design to work as a single element antenna or can be integrated to a MIMO antenna system working in the dual frequency band of (38/60 GHz) for 5G mobile communications systems.

The present work proposes a four-port MIMO antenna system for 5G mobile phones composed of modified rectangular patch antenna shown in [22]. The proposed modified rectangular patch antenna is composed of two patches; the primary patch is directly fed through a microstrip line with inset feed whereas the secondary patch is indirectly fed by coupling to the primary patch. A four-port MIMO antenna system is constructed of four elements of the proposed modified microstrip patch antenna. The separations between the four antennas lead to the spatial diversity required for the targeted 5G applications allowing high performance at high data rates. The MIMO antenna system performance including the return loss at each antenna port and the coupling coefficients between the different ports is investigated and shown to be suitable for 5G mobile communications. The radiation patterns produced when each port is excited alone are shown to be suitable for an efficient diversity scheme. The performance measures such as the envelope correlation coefficient (ECC) and diversity gain (DG) are evaluated showing excellent performance of the proposed MIMO antenna system.

The remaining part of the proposed paper is organized as follows. Section 2 proposes a four-port MIMO antenna system that employs antenna diversity for enhancement of the wireless channel performance. Section 3 presents the simulation results concerned with the proposed modified patch and the MIMO antenna system performance with detailed discussions. Section 4 is dedicated to describe the antenna fabrication and the experimental measurements. Section 5 includes comparisons between the results of the present work and those presented in other published work. Finally, Section 6 is devoted to the most important conclusions of the present work.

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2. THE PROPOSED FOUR-PORT MIMO ANTENNA SYSTEM FOR USER EQUIPMENT

To construct an optimized compact-size dual-band MIMO antenna system with low loss and minimum power consumption, it is proposed to use a dual-band small-size radiating element. The dimensions of the single element are given in Figure 1(a) where the dimensions are inspired by the design of [22]. It is designed to radiate in the dual frequency bands centered at 38 and 60 GHz. This antenna can be viewed as composed of two patches; the first patch is fed through a direct microstrip line with an inset feed, while the second is fed through capacitive (edge) coupling with the first patch.

The dimensions of the first patch are designed so that the first patch operates in its first-order mode at 38 GHz while the combined structure of the first and second patches is designed to have its first-order mode radiating at 60 GHz. At 38 GHz the radiation pattern is produced by the well-known first-order mode of the first patch which is omnidirectional in the azimuth plane (x-y) and has a balloon-like shape in the (elevation) E- and H-planes. The second patch has no contribution to the radiation at 38 GHz because of its small dimensions and the gap separation between both patches.

On the other hand, the cuts made in the first patch, specifically at the corners on both sides of the microstrip line, help to diminish the slot fields and surface currents near these regions thus preventing the formation of higher-order modes in the cavity below the combined-patch structure. Consequently, the radiation pattern at 60 GHz has a shape which is similar (to some extent) to that radiated by a rectangular patch operating at its first-order resonance.

TABLE 1. Dimensions of Design "A".

Dimension	Value (mm)
LP_1	2.05
LP_2	1.2
WP_1	2.6
WP_2	1.42
GP	0.6
L_{ins}	0.739
W_{ins}	0.11

To construct a four-port MIMO antenna system for operation at 38/60 GHz, four elements of the dual-band microstrip patch antenna with the dimensions shown in Figure 1(a) are arranged as shown in Figure 1(b). The separations between the four antennas are set so as to achieve the spatial diversity required for the target 5G applications. Such a MIMO antenna system allows high data rates for mobile communications with high performance. Let the design with the dimensions presented in Figure 2 be named design "A" with the dimensions presented in Table 1. This design is compact (total dimensions 20 x 20 mm2) with short feeding lines

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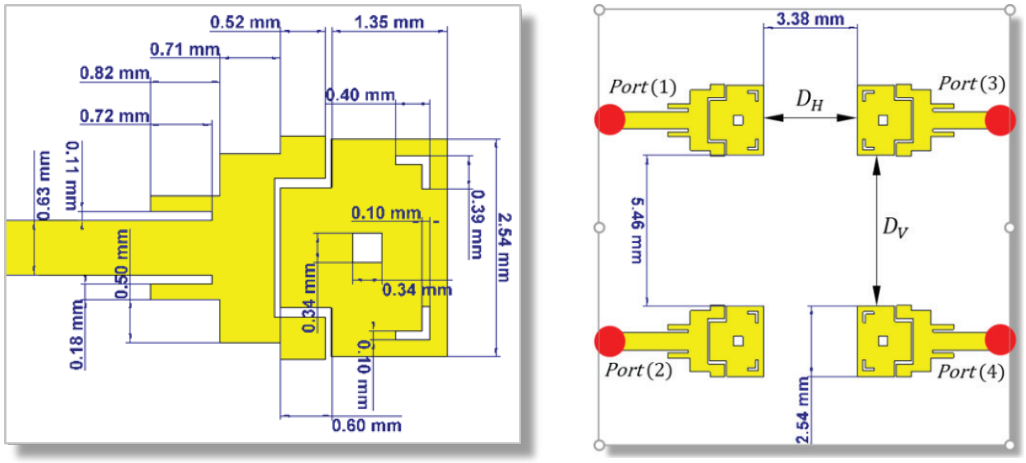
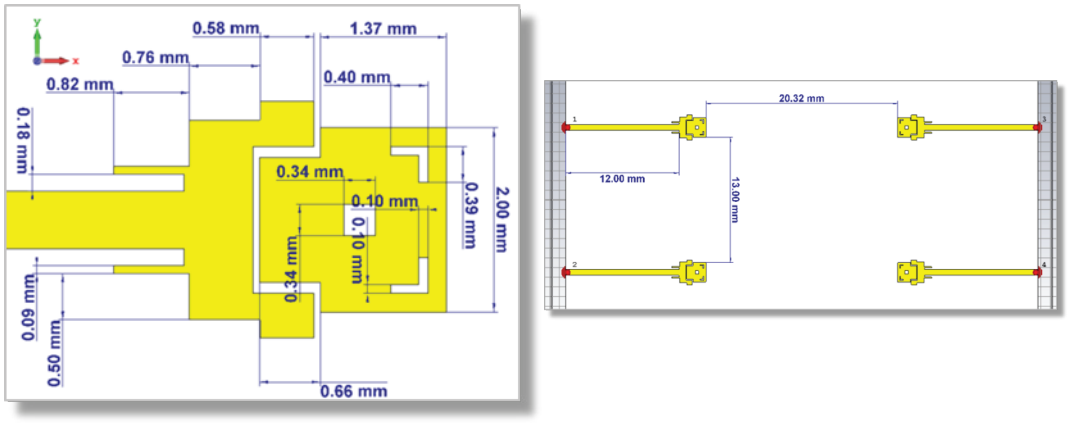
and reasonable separations between the four antennas. Such a MIMO antenna system can be practically suitable to be manufactured and integrated on a printed electronic board of a mobile handset as no bulky millimeter-wave connectors are required in this case. However, such an antenna system design may be inappropriate to be connected to a microwave source for the purpose of laboratory experimental investigations.

Design "B", shown in Figure 2, gives alternatives for both the single element and the four-port MIMO system designs that are more suitable for experimental investigations in millimeter-wave laboratories. The longer feedlines of this design allow experimental measurements through coaxial launch connectors. Such commercially available connectors are bulky and may affect the antenna operation if they are connected to short feedlines like those of design "A". The total area of the MIMO antenna system with design "B" is 50 x 30 mm^2, which is about four times the area of that with design "A". It should be noted that both the horizontal and vertical separations between the antenna elements in design "B" are larger than those in design "A" for the enhancement of the diversity gain.



(a) (b)

Fig. 1. (a) Dual-band patch antenna, (b) Four-port MIMO antenna system (total dimensions of 20 x 20 mm^2) proposed for 5G mobile handsets (design "A").



(a) (b)

Fig. 2. (a) Dual-band patch antenna, (b) Four-port dual-band MIMO antenna system (total dimensions 50 x 30 mm^2) proposed for fabrication and experimental investigation (design "B").

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3. SIMULATION RESULTS AND DISCUSSION

In this section, the performance of the dual-band patch antenna and that of the four-element MIMO antenna system are investigated and the corresponding numerical results are presented and discussed. The return loss and radiation patterns of the single antenna and MIMO system are investigated. Furthermore, the results are concerned with the coupling coefficients, the radiation patterns, the diversity gain (DG) and the corresponding envelope correlation coefficient (ECC) of the four-port MIMO antenna configuration. The performance of both designs "A" and "B" for the MIMO system are investigated with experimental investigations for design "B".

3.1. Performance Assessment of the Dual-band Microstrip Patch Antenna

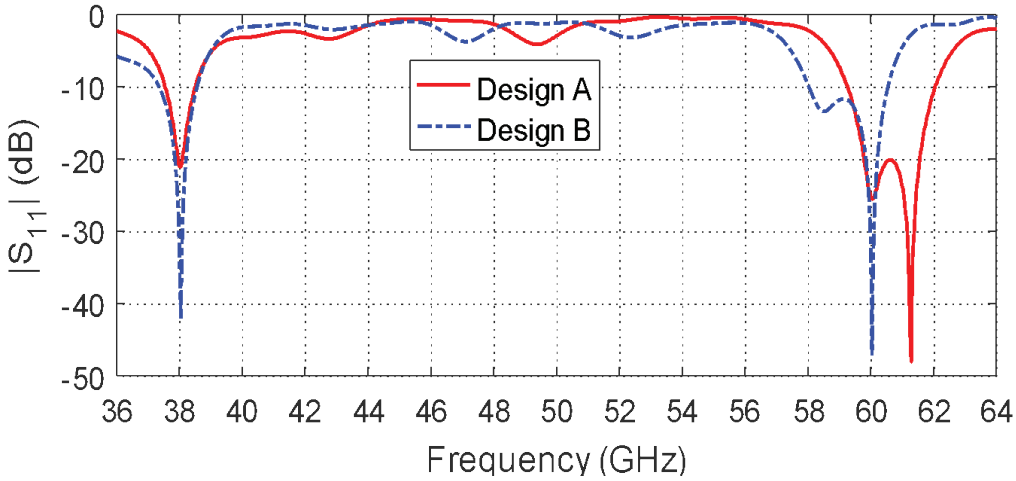

Fig. 3. Dependence of the simulated reflection coefficient, |Ss11| on a wide band of frequency for the proposed dual-patch antenna (for both designs "A" and "B").

The dependence of the simulated reflection coefficient, $|Ss_{11}|$ of the proposed dual-patch antenna is presented in Figure 3. It is shown in the figure that the antenna impedance of designs "A" and "B" are perfectly matched at the frequencies 38 and 60 GHz. Design "A" has return loss of -21 and -25 dB at 38 and 60 GHz, respectively. Design "B" is shown to have return loss of -42 and -47 at 38 and 60 GHz, respectively which outperforms design A with lower return loss at both operating bands.

The radiation patterns for the proposed dual-band antenna at 38 GHz for both design "A" and design "B" are presented in Figure 4(a) and Figure 4(b), respectively in the E-plane (ϕ =0°) and H-plane (ϕ =90°) to show that a balloon-like shape is achieved. Similarly, Figures 5(a) and 5(b) depict the balloon-like shape of the 60 GHz for designs "A" and "B". Figures 6(a) and 6(b) highlight the omnidirectional shape of the radiation patterns at 38 GHz for both designs ("A" and "B"), respectively in the azimuth planes (θ =const) in addition to the same azimuth radiation patterns obtained for 60 GHz shown in Figures 7(a) and 7(b). The maximum gain is about 6.5 dBi at 38 GHz, and is about 5.5 dBi at 60 GHz. Such radiation patterns are proper for MIMO antenna system composed of multiple units of such dual-band radiating elements.

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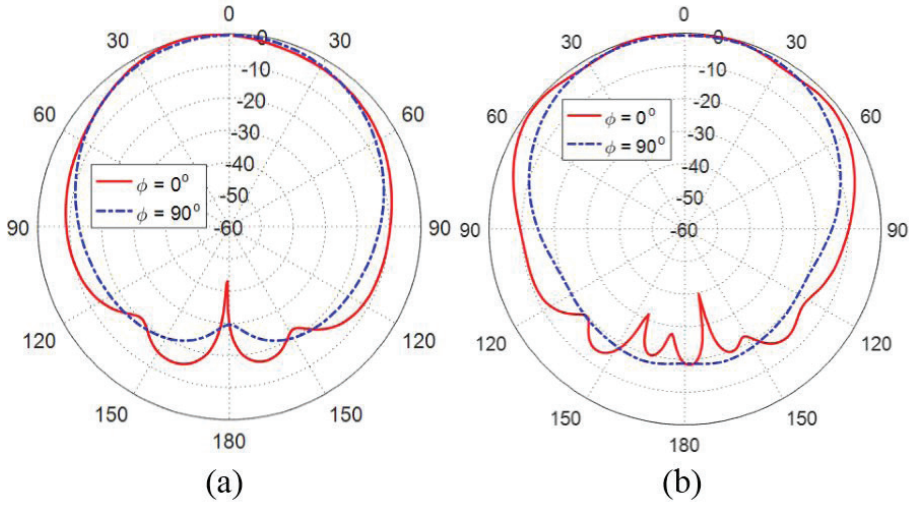

Fig. 4. Radiation patterns in the elevation planes at 38 GHz for the dual-band microstrip patch antenna, (a) design "A" and (b) design "B".

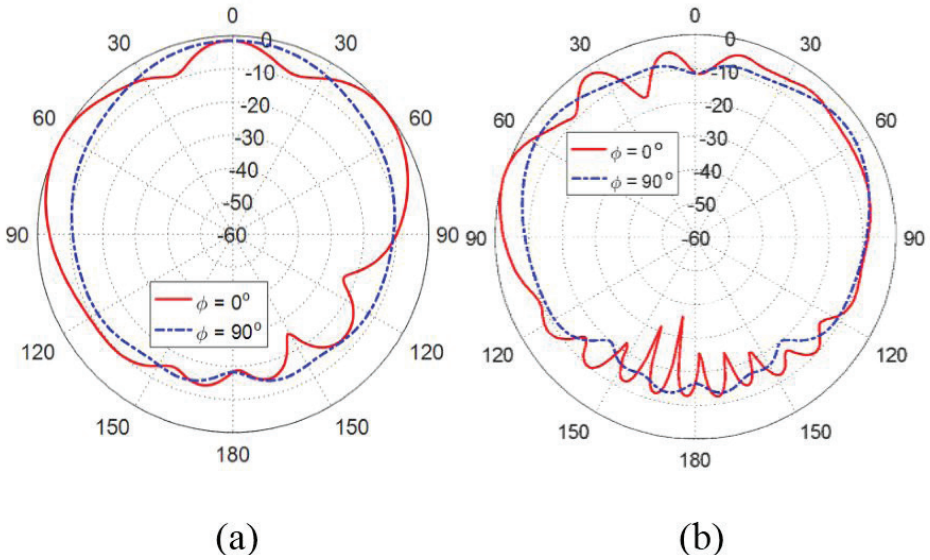

Fig. 5. Radiation patterns in the elevation planes at 60 GHz for the dual-band microstrip patch antenna, (a) design "A" and (b) design "B".

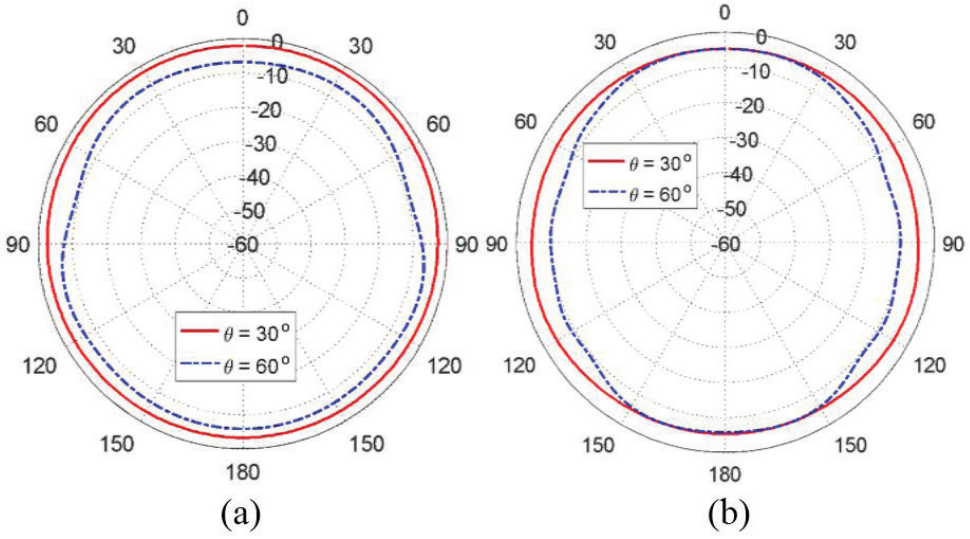

Fig. 6. Radiation patterns in the azimuth planes at 38 GHz for the dual-band microstrip patch antenna, (a) design "A" and (b) design "B".

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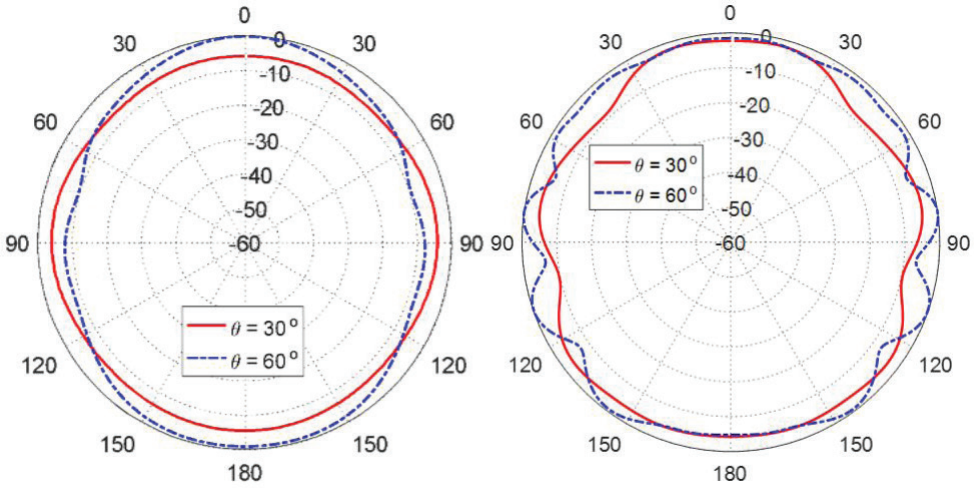

Fig. 7. Radiation patterns in the azimuth planes at 60 GHz for the dual-band microstrip patch antenna, (a) design "A" and (b) design "B".

3.2. Self and Mutual Coupling Coefficients for the Four-Port MIMO Antenna System

The dependence of the various self and mutual scattering parameters for the four-port MIMO antenna configuration, design "A", on the frequency is presented in Figure 8. It is shown that the self-scattering parameters representing the reflection coefficients at the antenna ports are almost identical over the entire frequency range and satisfy the impedance matching condition (low return loss) over the lower and upper frequency bands which are centered at 38 GHz and 60 GHz, respectively. The mutual scattering parameters show very weak coupling between the antennas' ports, where all these coefficients are maintained below -20 dB over the entire frequency range except for the coefficients $|S_{31}|$ and $|S_{42}|$ which exceed -20 dB at the resonant frequencies of the MIMO antennas. This is attributed to the relatively small horizontal separating distance between the antennas connected to ports (1) and (3) and that between the antennas connected to ports (2) and (4) as shown in Figure 2. However, for better performance regarding the coupling coefficients, the horizontal separation can be a little bit increased. Nevertheless, the effect of both the vertical and horizontal separations between the antennas significantly affects the coupling coefficients and such an effect is investigated later on.

On the other hand, for MIMO antenna system of design "B", the frequency response of the various self and mutual scattering parameters is presented in Figure 9. The self-scattering parameters at the antenna ports show impedance matching over the lower and upper frequency bands with better performance than that achieved by design "A". Also, the mutual scattering parameters show very weak coupling between the antennas' ports, where all these coefficients are maintained below -30 dB over the entire frequency band. Owing to the wider separation distances between the elements, the isolation between the antenna ports is significantly better than that achieved by the MIMO antenna system of design "A".

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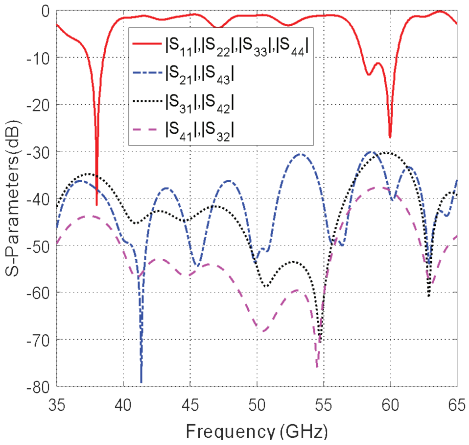

Fig. 8. Dependence of the self and mutual scattering parameters of the proposed four-port MIMO antenna system of design "A" on the frequency over a wide band.

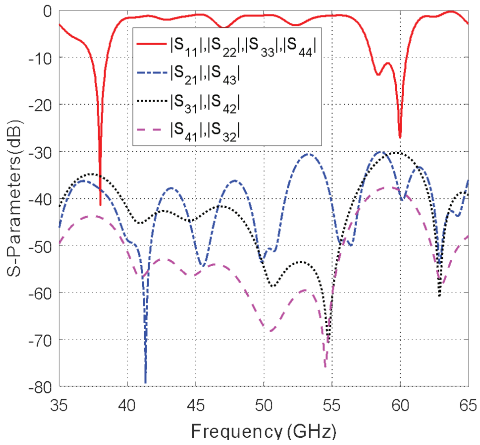

Fig. 9. Dependence of the self and mutual scattering parameters of the proposed four-port MIMO antenna system of design "B" on the frequency over a wide band.

3.3. Study of the Isolation between the Antenna Ports through the Surface Current Distribution

The mutual coupling between the antenna ports in a MIMO antenna system can be investigated by studying the surface current distribution on the patch antennas when a single port is excited alone. It is shown in Figure 10 that the surface current almost vanishes on the unexcited patches at 38 GHz. As shown in Figures 10(a) and 10(b), the surface current has a large value on the feedlines and on the patches attached to the (excited) ports "1" and "3", respectively and is almost zero elsewhere. This gives a strong indication to a high level of isolation between the antenna ports; that is there is almost no mutual current induced on the unexcited antenna elements. Figure 11 shows the current distribution on the excited patch surface (attached to port "1") at 38 GHz. As shown in this figure, the current is concentrated on the first patch and is negligible on the second patch showing the same behavior of a single antenna element radiating at 38 GHz.

At 60 GHz, the surface current distribution is presented in Figures 12(a) and 12(b) when each of the ports "1" and "3", respectively, is excited alone. One of the known coupling mechanisms of printed antennas is the surface waves propagating on the substrate-air interface. This can be seen in the area surrounding the excited patches where the (circular) wave fronts of the propagating surface waves are formed as concentric circular patterns of the surface current distribution on the top surface of the substrate. In comparison to Figures 10(a) and 10(b) for the surface waves generated at 38 GHz, the surface waves generated at 60 GHz seem to be stronger. This results in that the magnitude of the coupling coefficients $|S_{31}|$ and $|S_{42}|$ at 60 GHz is greater than its magnitude at 38 GHz as already shown in Figures 10 and 13 which show the current distribution on the excited patch surface (attached to port "1") at 60 GHz. As shown in Figure 13, the current is nearly equally distributed on the first and second patches showing the same behavior of a single antenna element operating at 60 GHz where the combined structure of the two patches is responsible for the radiation into the far zone.

It should be noted that when exciting each of the ports "2" and "4" alone, identical surface current distributions described for port "1" and "3" exist on the corresponding

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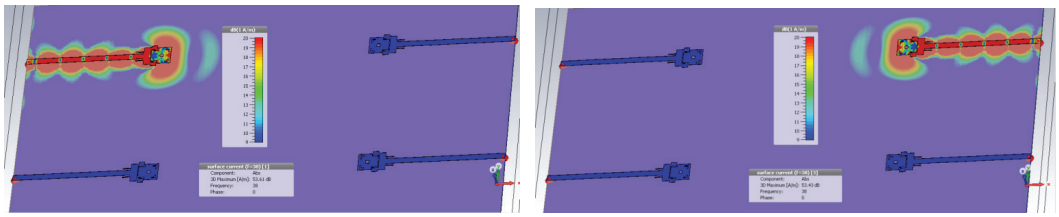
patches and their surrounding areas on the substrate top surface at both 38 and 60 GHz.



(a) (b)

Fig. 10. Surface current distribution on the four patches and the substrate when a single port is excited at 38 GHz, (a) port "1" is excited alone, (b) port "3" is excited alone.

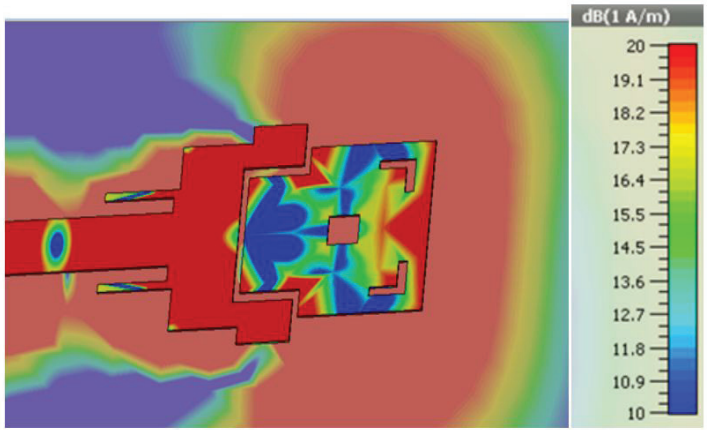
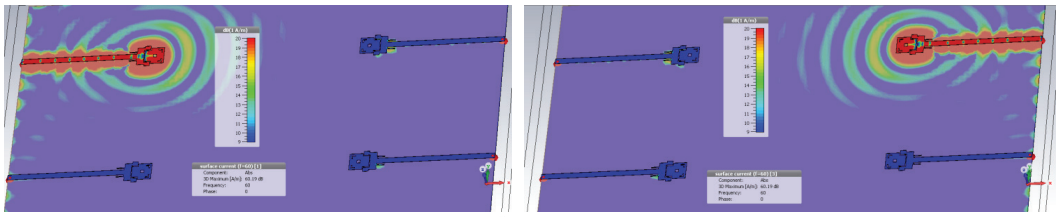


Fig. 11. Surface current distribution on the excited patch and the surrounding area of the substrate when a port "1" is excited alone at 38 GHz.



(a) (b)

Fig. 12. Surface current distribution on the four patches and the substrate when a single port is excited at 60 GHz, (a) port "1" is excited alone, (b) port "3" is excited alone.

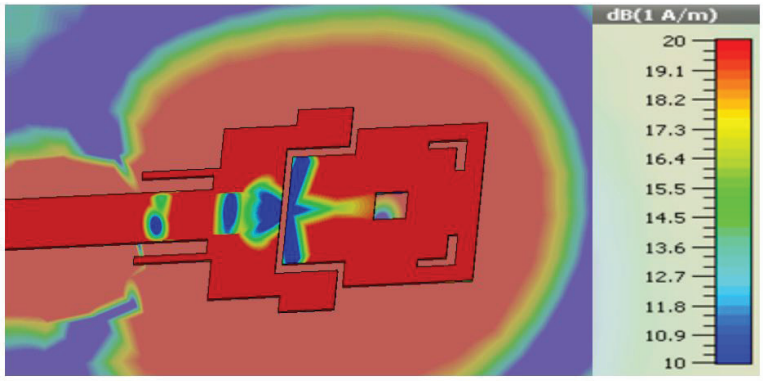


Fig. 13. Surface current distribution on the excited patch and the surrounding area of the substrate when port "1" is excited alone at 60 GHz 60 GHz.

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3.4. Parametric Study of the Separation between the Patch Antennas on the Performance of the MIMO Antenna System

The horizontal and vertical separations D_H and D_V have major effects on the performance of the MIMO antenna system. Decreasing the separation between the adjacent antennas increases the mutual coupling between them, which, in turn has bad effects on the self-impedance of each element of the MIMO antenna system. Also, the ECC and the DG are badly affected by decreasing the separations between the antennas in a MIMO system. On the other hand, increasing the distances between the antennas may be limited by the physical dimensions of the supporting frame of the mobile handset itself. The following subsections are dedicated for presenting and discussing the possibility of increasing the separating distances between the elements of the proposed MIMO antenna system on the VSWR of the elements, the coupling coefficients between the different ports, the ECC and the DG of the MIMO system. Definitely, the horizontal separation, D_H, in both the proposed designs "A" and "B" has a greater effect on the MIMO system performance than the vertical separation, D_V as the direction of propagation of the substrate surface waves is horizontal as seen in the surface current distribution presented in Fig. 10 and Fig.12.

3.4.1. Effect of the separation between the patch antennas on the VSWR at the antenna ports

The effects of the horizontal separation on the VSWR at each of the four ports of the proposed MIMO system of design "B" are presented in Figure 14 at 38 and 60 GHz. As shown in the figure, the VSWR seems to be independent of the horizontal separation and each of the four antennas is perfectly matched even when the antennas are very close to each other. The VSWR calculated for a horizontal separation of 1 mm is almost equal to that calculated for a separation of 20 mm. This can be attributed to the design of the antenna with dual-patch structure that concentrates the fields beneath the first patch in a region far enough from the front edge of the second patch. Also, the weak mutual effects among the antennas is owed to the selected thin substrate which confines the fields in the dielectric region just below the radiating patches and, thereby, reduces the region into which the field is fringing preventing it from arriving to the other antennas. Moreover, this substrate is characterized by its very low loss due to its very small loss tangent (δ=0.001) which reduces the substrate currents. The surface waves generated in low-loss thin substrate at one antenna are too weak to arrive at the other antennas even when they are very close to each other.

3.4.2. Effect of the separation between the patch antennas on the coupling coefficients

The frequency responses of the mutual coupling coefficients between each pair of the four antennas of the MIMO system of design "A" are presented in Figures 15 (a) and 15(b) for different values of the horizontal and vertical separations, respectively. As shown in the figures, decreasing the horizontal separation has a worse effect on the coupling coefficients than the effect of decreasing the vertical separation. Increasing both the horizontal and vertical separations leads to global and monotonic decrease of the coupling coefficients, which in turn, enhances the MIMO antenna performance and increases the diversity gain. The drawback of increasing the separations between the printed patch antennas is the increase of the MIMO antenna size. It is shown that increasing the horizontal separation from 3.38 mm to 6.38 mm has the effect of decreasing the maximum coupling coefficient from about -18 dB to about -22.5 dB. To compromise between the MIMO antenna size and the performance regarding the mutual coupling between the four antennas, it

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may be recommended to set the horizontal separation to 6.38 mm and to set the vertical separation to 2.46 mm for the MIMO system of design "A".

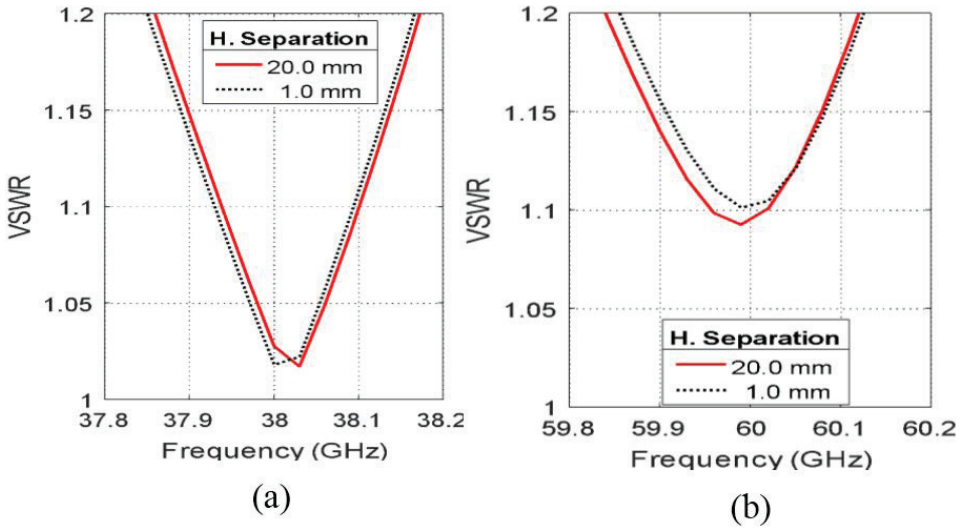

Fig. 14. Dependence of the VSWR on the frequency for all the four ports of the proposed MIMO system of design "B" for different values of the horizontal separation, D_H at (a) 38 GHz and (b) 60 GHz.

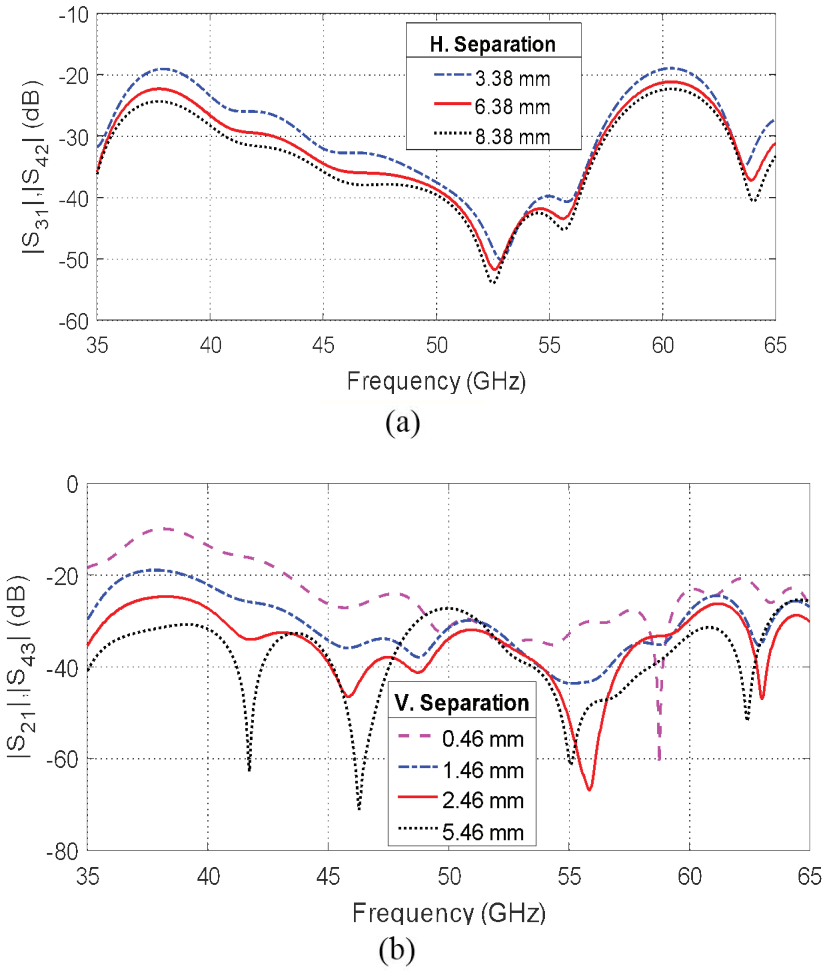

Fig. 15. Frequency dependence of the mutual coupling coefficients between the antenna elements of the four-port MIMO system of design "A" for different values of (a) horizontal separations, DH and (b) vertical separations between the patches, DV.

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3.4.3. Effect of the separation between the patch antennas on the ECC and DG

The frequency responses of the ECC and the DG of the proposed four-port MIMO antenna system of the design "A" are presented in Figure 16 for different values of the horizontal separation between the antennas. As shown in the figure, increasing the separating distances between the antennas of the MIMO system improves the ECC and DG. Also, it is shown that at the center frequencies of the lower and upper bands of the antenna operation (38 and 60 GHz) and over the entire width of each band, the ECC is very low (almost 0) and, consequently, the DG is almost 10 for all the values of the horizontal separating distance between the antennas. This is considered to be the best achievable performance for a MIMO antenna system.

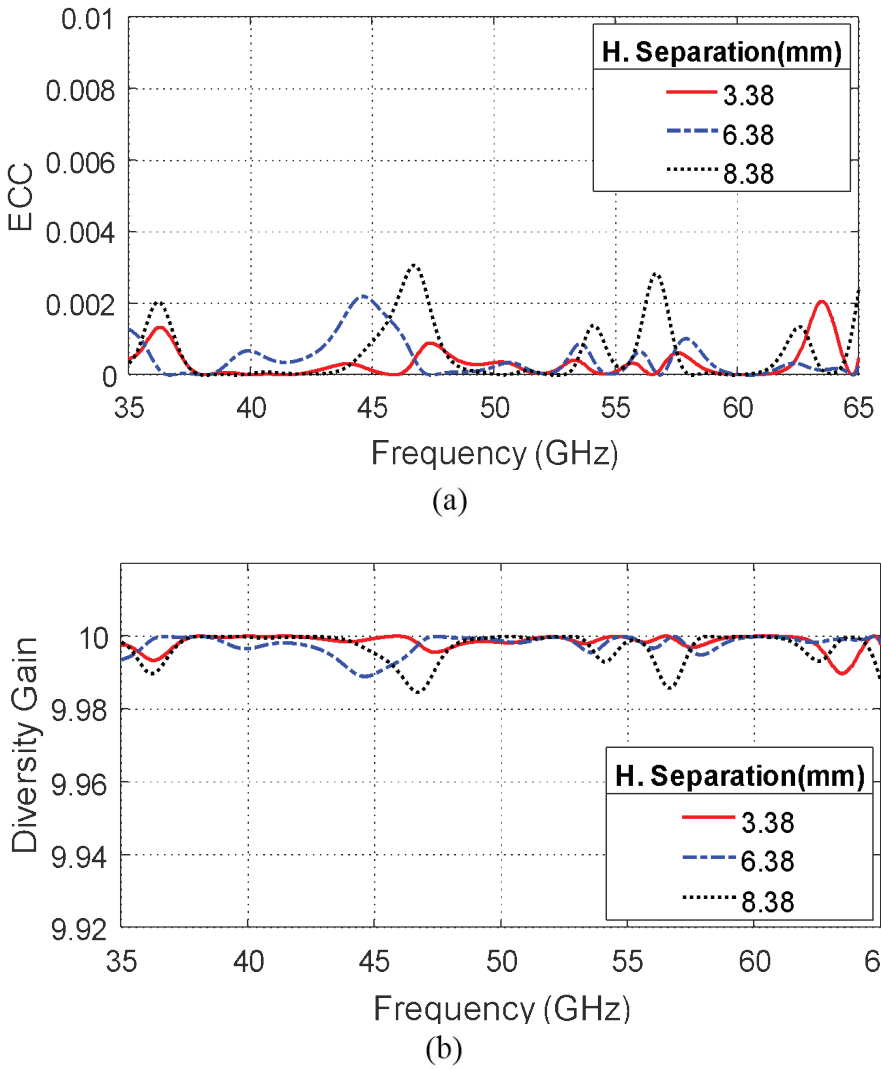

Fig. 16. Frequency dependence of the (a) ECC and (b) DG of the four-port MIMO antenna system of design "A" for different values of the horizontal separation distance between the patches.

3.5. Radiation Patterns of the MIMO Antenna System

The radiation patterns produced by the proposed MIMO antenna system of the design "A" when exciting each port alone at f=38 GHz and f=60 GHz are presented in Figures 17 and 18, respectively. It is shown that the produced radiation patterns are omnidirectional in the azimuth planes and have the balloon-like shape in the vertical

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planes which are recommended for the 5G mobile phone MIMO antennas. It is also noticed that the radiation pattern produced when exciting each port alone is not badly affected by the other unexcited antennas. Besides the reasonable size of the overall MIMO antenna system and the fairly long distances between the antennas that produce high diversity gain, the radiation patterns provide excellent solution for an efficient operation as a 5G mobile phone antenna.

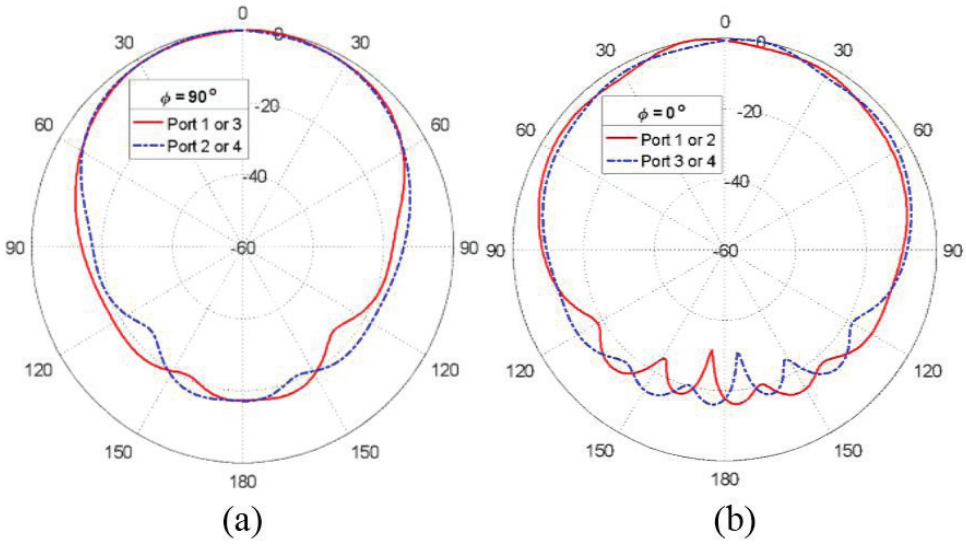

Fig. 17. Radiation patterns in the (a) H- and (b) E-planes for the proposed four-port MIMO antenna system of the design "A" using the dual-band microstrip patch proposed in the present work at f=38 GHz.

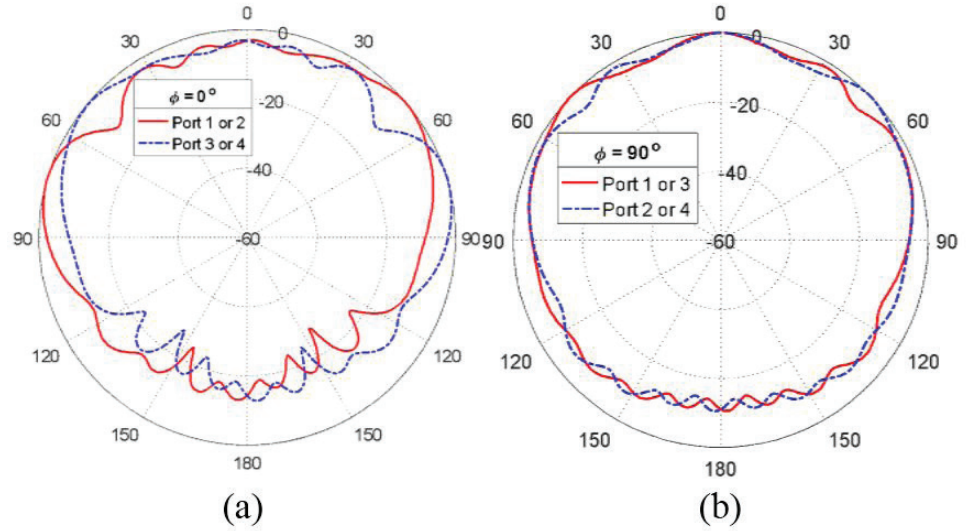

Fig. 18. Radiation patterns in the (a) E- and (b) H-planes for the proposed four-port MIMO antenna system of the design "A" using the dual-band microstrip patch proposed in the present work at f=60 GHz.

3.6. Efficiencies of the MIMO Antenna System

The radiation and total efficiencies of the proposed four-port MIMO antenna system of the design "B" when each port is excited alone are listed in Table 2. At both operating frequencies of the proposed MIMO antenna system, the radiation efficiency can be considered fairly high with respect to the relatively high values of the operating frequencies.

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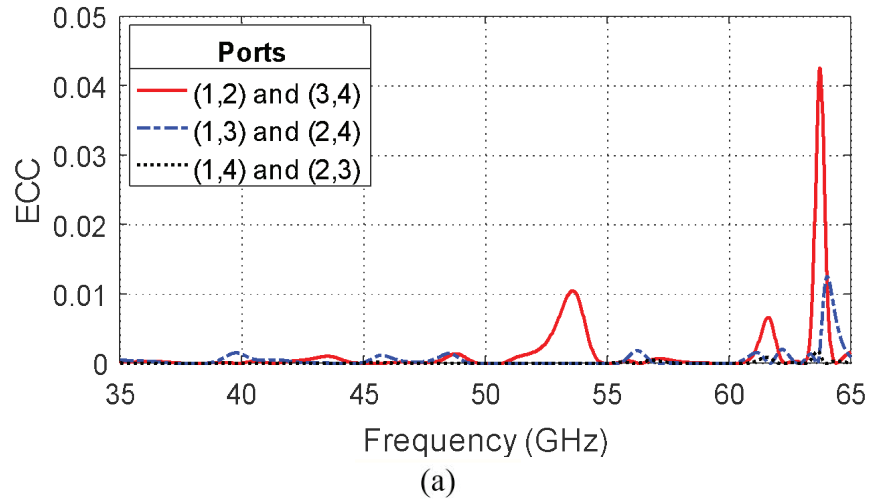
TABLE 2. Radiation and Total Efficiencies of the Proposed Four-port MIMO Antenna System of the Design "B".

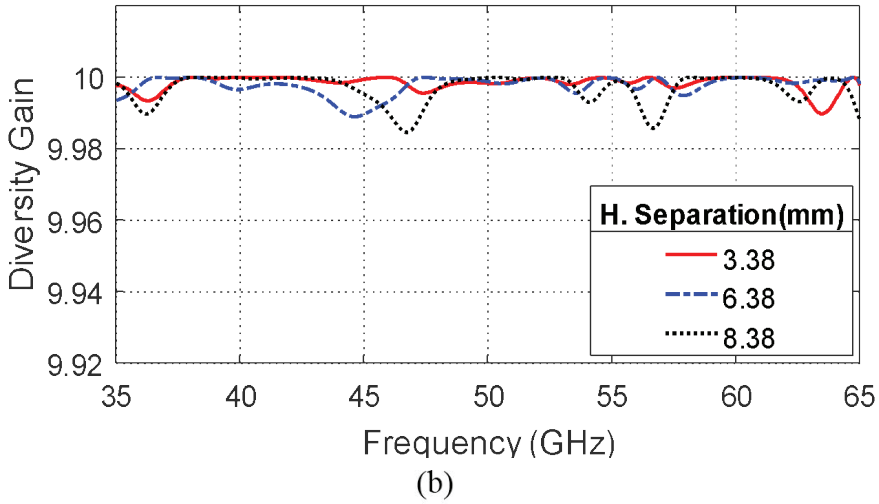
Horizontal Separation	Efficiency	Frequency (GHz)	
		38	60
20.0 mm	Total	89.4%	78.1%
	Radiation	89.37%	77.8%
1.0 mm	Total	89.87%	79.0%
	Radiation	90.11%	79.5%

3.7. Envelope Correlation Coefficient and Diversity Gain

The dependencies of the ECC and the DG of the proposed four-port MIMO antenna system of the design "B" on the frequency are presented in Figure 19. It is shown that at the operating frequencies 38 and 60 GHz and over the entire width of the lower and upper bands, the ECC is very low (almost 0) and, consequently, the DG is very high (almost 10). This can be considered as the optimum performance of MIMO antenna system. It should be noted that the relative positions of the antennas in the pair (1, 2) are the same as those in the pair (3, 4); this leads to identical ECC and DG as shown in Figure 19. The same applies for the antenna pairs (1,3) and (2,4) and, also, for the antenna pairs (1,4) and (2,3).



(a)



(b)

Fig. 19. Frequency dependence of the (a) ECC and (b) DG of the four-port MIMO antenna system of the design "B".

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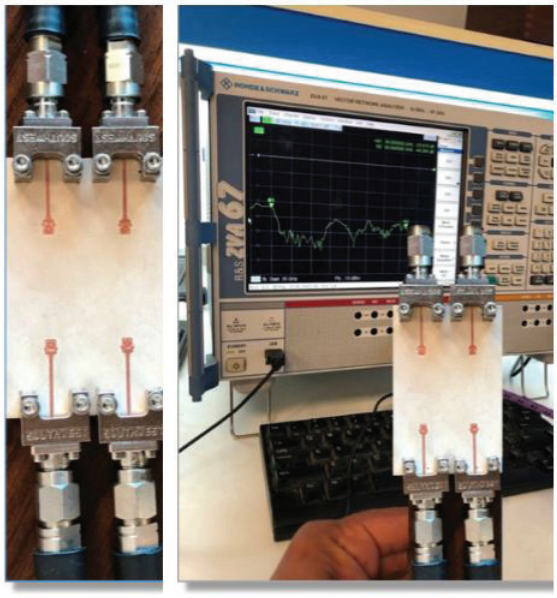
4. FABRICATION AND MEASUREMENTS OF THE MIMO ANTENNA SYSTEM PROTOTYPE

This section is concerned with the presentation of the experimental measurements of the four-port MIMO antenna system constructed by the dual-band microstrip patch antenna described above. Prototypes are fabricated for the four-port MIMO antenna system of the design "B". To confirm the accuracy of the assessed performance for the proposed MIMO antenna system, the measurement results are compared to those obtained by electromagnetic simulation using the commercially available CSTTM software package.

4.1. Measurements of the Return Loss at Each Port

The prototype shown in Figure 20(a) is fabricated for the purpose of experimental assessment of the performance of the proposed dual-band four-port MIMO antenna system. The vector network analyzer (VNA) Rhode and Schwartz model ZVA67 is used for measuring the frequency response of the reflection coefficients $|S_{11}|$ and $|S_{22}|$ at the ports "1" and "2" (the corresponding measurements for ports "3" and "4" are almost identical). Two 1.85 mm end-launch connectors from Southwest Microwave Incorporation are used for connecting the corresponding antennas to the VNA as shown in Figure 20(b).



(a) (b)

Fig. 20. Measurement of the reflection coefficients $|S_{11}|$ and $|S_{22}|$ of the proposed four-port MIMO antenna system using the VNA Rhode and Schwartz model ZVA67. (a) Fabricated prototype, (b) Measurement of the S-parameters.

The frequency dependencies of $|S_{11}|$ and $|S_{22}|$ are presented in Figure 21 (relative to 50 Ω characteristic impedance of the microwave source) compared to the simulation results showing excellent agreement. The measured bandwidths over which |S11|< -10 dB $|S_{11}|$ <-10dB are shown to be wider than those obtained by simulation. The bandwidth measured at 38 GHz is about 2.0 GHz, whereas the bandwidth obtained by simulation is about 1.2 GHz. The measured bandwidth at 60 GHz is about 3.2 GHz, whereas the simulated one is about 2.52 GHz. It is shown that the width of upper frequency band obtained by measurements is centered at about 60 GHz, whereas the upper band obtained by simulation is shown to be shifted towards the left and centered at about 59 GHz. It is shown that the center frequency of the

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lower band measured at port "2" is slightly shifted towards the right.

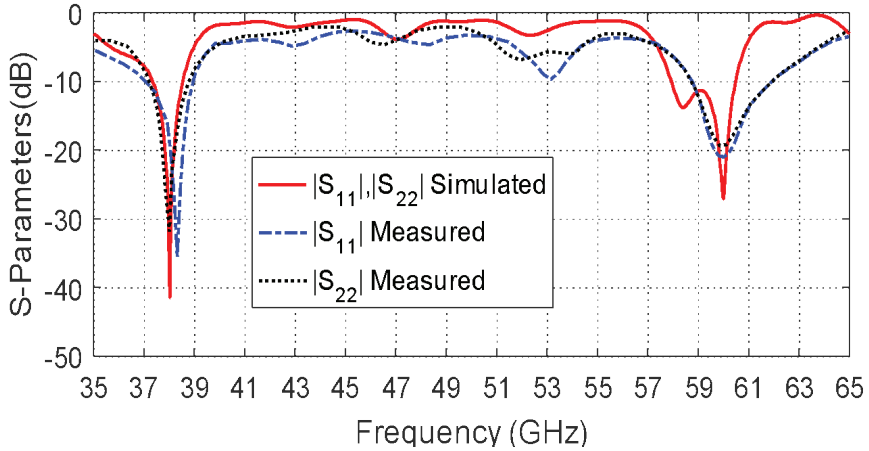

Fig. 21. Measured frequency responses of the reflection coefficients, $|S_{11}|$ and $|S_{22}|$, of the proposed dual-band four-port MIMO system.

4.2. Measurements of the Isolation between the Ports

The frequency responses of the transmission coefficient, $|S_{21}|$, of the proposed dual-band four-port MIMO antenna system of design "B", obtained by experimental measurements are presented in Figure 22 compared to those obtained by simulation. Both simulation and experimental results show very low values of the mutual coupling between the antennas connected to ports "1" and "2" over the entire frequency range. This indicates very high performance of such a MIMO antenna system regarding the ECC and DG.

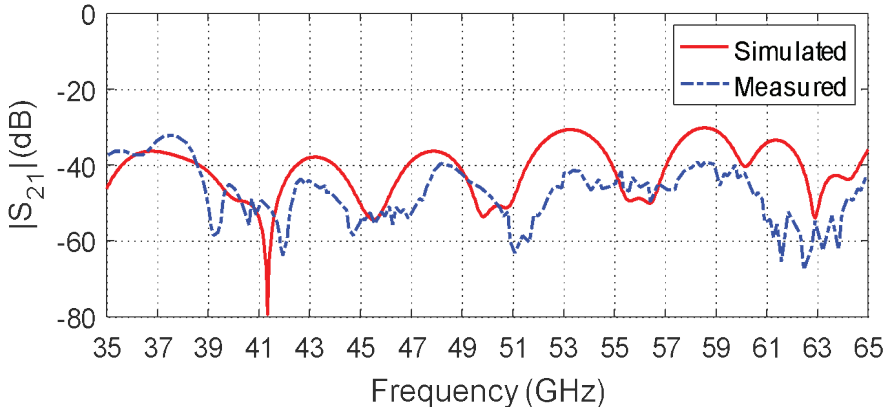

Fig. 22. Measured frequency response of the transmission coefficient, $|S_{21}|$, of the proposed dual-band four-port MIMO antenna system (relative to 50 Ω characteristic impedance of the microwave source) compared with the simulation results.

4.3. Measurements of the Radiation Patterns and Maximum Gain for Each Port

The experimental setup for measuring the radiation patterns and the maximum gain of the proposed four-port MIMO antenna system is presented in Figure 23. The VNA Rhode and Schwartz model ZVA67 operating in the two-port measurement mode is used for this purpose by measuring the transmission coefficient $|S_{21}|$ through the antenna under test and the reference-gain linearly-polarized horn antennas models LB-018400 (for 38 GHz band) and LB-12-10-A (for 60 GHz-band).

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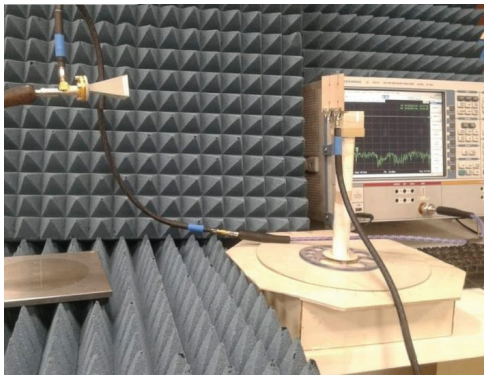
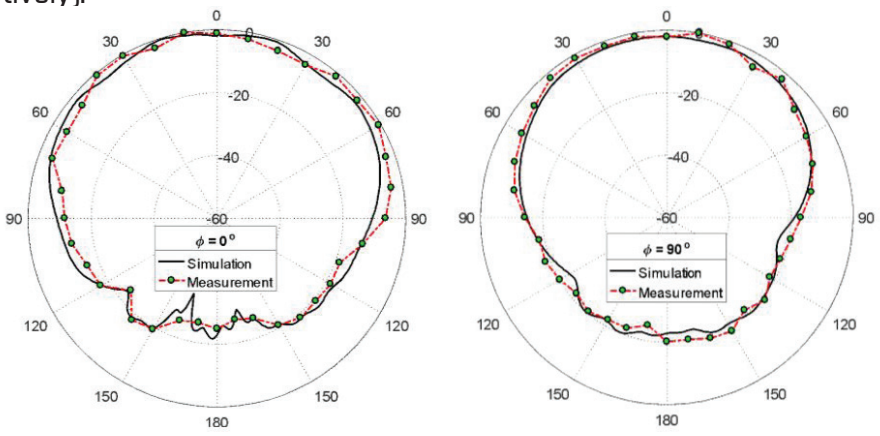


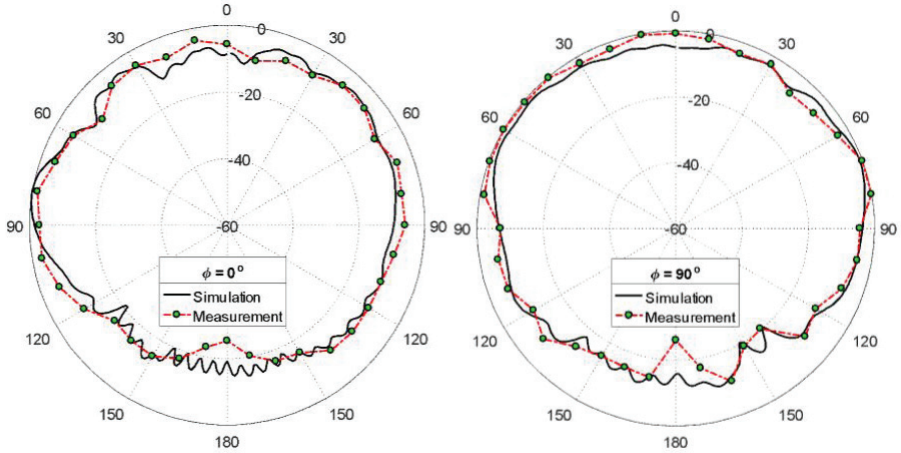
Fig. 23. Experimental setup for measuring the radiation pattern and gain while exciting each port of the MIMO antenna system alone.

The elevation radiation patterns measured in the planes ϕ =0° (E-plane) and ϕ=90° (H-plane) of the proposed four-port MIMO antenna system of design "B" are presented in Figures 24 and 25 at 38 GHz and 60 GHz, respectively. The measured and simulated radiation patterns show good agreement. The maximum gain values obtained by measurement are 6.1 dBi and 5.2 dBi at 38 GHz and 60 GHz, respectively, which agree with the measured values (6.5 dBi and 5.5 dBi at 38 GHz and 60 GHz, respectively).



(a) E-plane ($\phi = 0°$) (b) H-plane ($\phi = 90°$)

Fig. 24. Measured radiation patterns at 38 GHz of the dual-band antenna compared with the simulation results while exciting each port of the MIMO antenna system of design "B".



(a) E-plane ($\phi = 0°$) (b) H-plane ($\phi = 90°$)

Fig. 25. Measured radiation patterns at 60 GHz of the dual-band antenna compared with the simulation results while exciting each port of the proposed four-MIMO antenna system of design "B".

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5. COMPARATIVE ASSESSMENT OF PERFORMANCE

In the frequency band centered at 38 GHz, the dependence of the reflection coefficient $|S_{11}|$ obtained for the MIMO antenna proposed in the present work on the frequency is compared to those presented in [23], [24] and [25] as shown in Figure 26. The corresponding values of the center frequencies, return loss and impedance matching bandwidth are specified in Table 3. It is shown that the present work outperforms other published work concerning the center frequency and corresponding return loss. The present impedance matching bandwidth is shown to be better than the work of [25] and is approximately the same as the work of [23] which has a higher value of the return loss compared to the present work.

In the frequency band centered at 38 GHz, the dependence of the coupling coefficient $|S_{21}|$ obtained for the MIMO antenna proposed in the present work on the frequency is compared to those presented in [17] and [28] as shown in Figure 27. The maximum value of the coupling coefficient achieved in the present work, [17] and [28] is stated in Table 4. This means that the ECC and consequently the DG achieved by the MIMO system proposed in the present work is superior to those introduced in the mentioned published results.

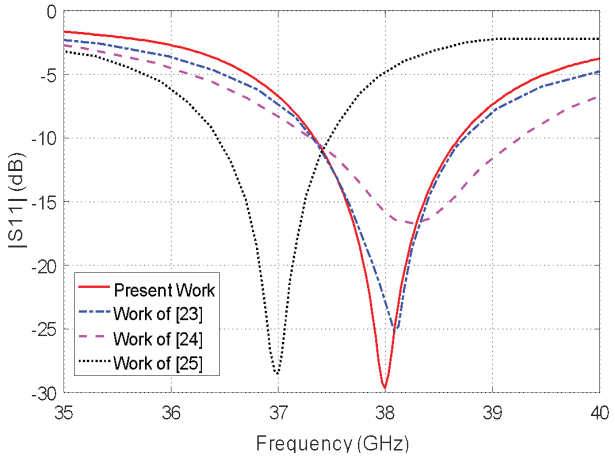

Fig. 26. Frequency response of the reflection coefficient, $|S_{11}|$, measured at port "1" of the MIMO antenna system proposed in the present work in the frequency band centered at 38 GHz in comparison to those presented in other publications.

TABLE 3. MIMO Antenna Performance at 38 GHz (Port 1)

Performance Measure	Work			
	[23]	[24]	[25]	Present
f_0 (GHz)	38.1	38.3	37.0	38.0
$\|S_{11}\|_{dB}$ (38 GHz)	-23	-15	-5	-30
BW (GHz)	1.4	2.0	1.0	1.4
Dimensions (mm)	55x110	6x6.25		50x30

In the frequency band centered at 60 GHz, the frequency response of the $|S_{11}|$ obtained for the antenna proposed in the present work through simulation is compared to those presented in [26] and [27] as shown in Figure 28. The minimum value of the return loss achieved in the present work, [26] and [27] is listed in Table 5. It is clear that the presented work surpasses the published work regarding the center frequency of the band of interest, return loss and impedance matching bandwidth. The bandwidth of the present work is about 4 times the work of [26] and has increased about 12 times the work of [27], which indicates a remarkable enhancement of the 60-GHz bandwidth.

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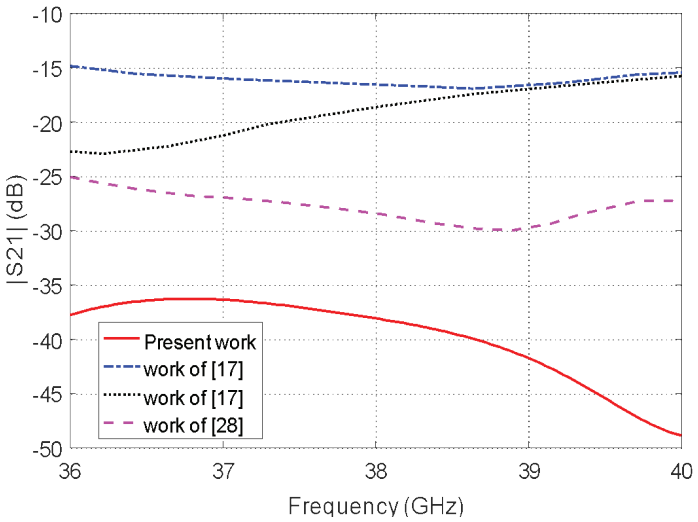

Fig. 27. Comparisons between the frequency responses of the coupling coefficients $|S_{21}|$ obtained in the present work for the proposed dual-band four-port MIMO antenna system in comparison to those obtained in [17] and [28] at 38 GHz.

TABLE 4. MIMO Antenna Performance at 38 GHz (Port 1 and 2)

Performance Measure	Work			
	[17]	[28]	[23]	Present
$\|S_{11}\|_{dB}$	-17	-12	-23	-28
$\|S_{22}\|_{dB}$	-15	-10	-23	-30
$\|S_{21}\|_{dB}$	-17	-28	-30	-38
ECC	1×10^{-7}	7×10^{-8}	1×10^{-10}	2×10^{-13}

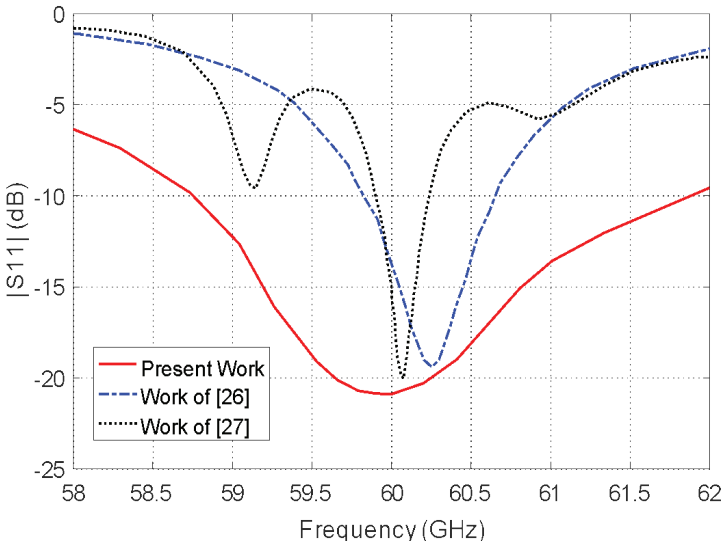

Fig. 28. Frequency response of the reflection coefficient, $|S_{11}|$, measured at port "1" of the MIMO antenna system proposed in the present work in the frequency band centered at 60 GHz in comparison to those presented in [26] and [27].

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Table 5. MIMO Antenna Performance at 60 GHz (Port 1)

Performance Measure	Work		
	[26]	[27]	Present
f_0 (GHz)	60.26	60.10	60.00
$\|S_{11}\|_{dB}$ (60 GHz)	-14	-15	-21
BW (GHz)	1.5	0.5	6.3

6. CONCLUSION

A novel design is introduced for four-port MIMO antenna system for 5G mobile phones. The proposed MIMO antenna is constructed of microstrip patch antennas with novel compact design to operate in the 38/60 GHz dual-band. The single antenna is constructed as primary and secondary rectangular patches with some geometrical modifications to fulfil the required impedance matching and balloon-like radiation patterns for the lower and the upper frequency bands of operation. The first patch is fed in a direct way using a microstrip line with an inset feed and is mainly responsible for the lower band (38 GHz) radiation. On the other hand, the second patch is responsible for the upper frequency band (60 GHz) radiation and is fed through both capacitive and inductive coupling to the first patch. The performance of both the single-element antenna together with the four-port MIMO antenna system is assessed numerically and experimentally through investigations for both. It is shown that the results of the simulation agree with the results of the experimental measurements, and both show good performance for the single antenna as well as the MIMO antenna system. Although the dimensions of the antenna are slightly larger than those published in previous works of literature. However, the proposed MIMO antenna dimensions do not impede it from being used in 5G systems. The achieved bandwidths around 38 GHz and 60 GHz are about 2 GHz and 3.2 GHz, respectively. The minimum values for the return loss are -42 dB at 38 GHz and -47 dB at 60 GHz. The gain has a maximum value of about 6.5 dBi at 38 GHz, and about 5.5 dBi at 60 GHz. The mutual coupling coefficients are below -30 dB over the operational frequency bands. Also, it is shown that the envelope correlation coefficient (ECC) and the diversity gain (DG) for the four-port MIMO antenna system are suitable over the lower and upper frequency bands.

Author Contribution: Conceptualization: M.S., R.K, A.Z., and M.O.; methodology, M.S.; software, M.S.;
validation, M.S., formal analysis, M.S., M.O.; investigation, M.S.; resources, M.S., A.Z., R.K. and M.O.; data curation, M.S.; writing—original draft preparation, M.S.; writing—review and editing, A.Z., R.K. and M.O.; visualization, M.S.; supervision, A.Z., R.K, and M.O.; project administration, M.S.

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Conflicts of Interest: The authors declare no conflict of interest.

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A Framework for Utilizing Unexplored Game Elements in Designing Learning Systems

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ABSTRACT

Gamification is defined as the use of game elements and designs in non-gaming areas and applications such as education, marketing, and healthcare. That is to facilitate and develop the engagement of users with a product or service. Researchers have found that gamified learning has the ability to improve student success, interaction, and enjoyment of courses. Recently, researchers suggested that one way to achieve that is through the personalization of students' experiences. However, research has been focusing on a narrow group of game elements which does not ensure equal consideration when designing for different personality types. In this paper, the reseachers' aim is threefold that is: to identify the unexplored game elements in the learning domain to ensure equal experiences for different personality traits; to study the utilization of the identified unexplored elements and how they can be used in relation with different personality types and learning styles to make learning tasks more desirable and enjoyable; to inform and enrich the design of gamified e-learning systems. To achieve that aim, the researchers analyzed the literature to identify the unexplored game elements, conducted a focus group study to examine the utilization of unexplored game elements along with other contextual aspects. Then to formalize the results reached from our study and provide more systematic means for software engineers to extract useful information that can inform their designs, an ontology was implemented for that purpose. Finally, an existing gamified e-learning framework was adapted to illustrate how the formed artifacts and models interrelate to realize the research aim.

Keywords: Gamification, Learning Styles, Ontology, Personality Traits, Software Engineering

1. INTRODUCTION

GAMIFICATION as a term was introduced in 2002 by Nick Pelling who described it as "applying game-like accelerated user interface design to make electronic transactions both enjoyable and fast" (Buckley et al., 2018). While Bartle in 2003 described gamification as "turning something not a game into a game" (Dal Sasso et al., 2017). Then in 2011, it was defined as "the use of game design elements in non-game contexts"(Tondello and Nacke, 2018). "Gamification is a noun, which means the use of game design, game elements, and play for non-entertainment purposes" as described in (Marczewski, 2015).

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Ever since its introduction, it has been employed in serious contexts to enhance engagement, motivation, and participation in order to change users' behavior (Tondello et al., 2016). Nowadays, gamification is emerging in many fields like Marketing (Buckley and Doyle, 2017), crowdsourcing (Morschheuser et al., 2016), software development (Dal Sasso et al., 2017; Buckley et al., 2018), government (Santos et al., 2015), and health (Tondello et al., 2016). In this paper, the researchers are more focused on gamification in education as it has been attracting attention in the context of education.
According to the calculations in statista (Greenfield, 2017), the gamification industry was forecasted to expand from $4.91 billion in 2016 to approximately $12 billion in 2021.

Users are the main intended audience of these systems and a key factor to its success. Thus, according to Landers (2019), to make gamification successful, more focus must be paid to the human factors. Otherwise, it will be called "Fake Gamification", which is a process that only adds decorative game elements to the systems without including elements that have an effect on human characteristics, extrinsic and intrinsic motivations (Dicheva et al., 2015; Jia et al., 2016). However, most gamification in education studies focuses only on a few game elements and neglecting the main purpose of gamification in education, which aid all students to immerse and effectively collaborate in the specified course or lecture (Akgün and Topal, 2018; Alsawaier, 2018; Rahman et al., 2018; Subhash and Cudney, 2018; Zahra et al., 2019).

Personalized content motivates users much further compared to "one size fits all" (Khaleel et al., 2016) leading to better course satisfaction (Buckley et al., 2018). According to Tondello and Nacke (2018) and Papamitsiou et al. (2020), customization and personalization achieve better results and are more effective than generic approaches. Researchers have attempted to personalize learning environments by using different factors such as age, gender, personality traits, user types, and learning styles (Jia et al., 2016; Buckley and Doyle, 2017; Lavoué et al., 2018; Shirsekar, 2019). With personalizing design and content, learning can become more effective by displaying the relevant content using the relevant style to the right users (El-Shorbagy et al., 2020).

On the other hand, other findings have demonstrated that the "one size fits all" approach raises risks such as undesired behavior and declining student performance (Toda et al., 2018; Landers, 2019). Examples from what researchers have found are that the effect of leaderboards differs according to personalities. It can positively or negatively influence performance according to personality type (Antonaci et al., 2019). Also, while rewards may be motivating for some users they can decrease the confidence of others (Toda et al., 2018).

Different researches were made on personalizing education experience by integrating it with big five personality traits (Tondello et al., 2016) or gamification player types (Akgün and Topal, 2018) and learning styles (Pornsakulvanich et al., 2012). Most researchers in gamified learning tried to find a better way for personalization by merging several factors. For example (Tondello et al., 2016; Tondello and Nacke, 2018), focused on the big five and some game elements. While mentioned learning styles and a couple of game elements (Zaric et al., 2017). In big five, and learning styles were presented (Konert et al., 2013). Others in attempted to gamify the learning experience according to the task nature (Rapeepisarn et al., 2008; Zaric et al., 2017). According to Landers (2019) and El-Shorbagy et al. (2020), there are user types neglected in the design of gamified learning systems as only a few elements correlated to them are used in learning applications and platforms. That is why

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gamification risks are emerging (Toda et al., 2018). Various gamification elements motivate different user types. They support gamification designs as they can be used as elements, emotion, feedback, mechanics, dynamics, or schedule depending on application purpose (Marczewski, 2015).
This paper presents a study that further explores the merging of four different factors: 1) game elements with a specific focus on un-explored game elements; 2) personality traits; 3) learning style; and 4) task nature, for a better-personalized design of learning systems that cover all the needs of different personality types and their motivators.

The use of gamification in designing and implementing learning systems is a challenging task. It includes knowledge about game elements (such as points and leaderboards), fundamental components of course management (such as required tasks), and other contextual information (such as learning styles and/or personality traits). To deal with this challenge, a formalized method is needed to support the concepts with the possibility of automated reasoning that helps inform design decisions in gamified learning systems. Researchers (García et al., 2017; Bouzidi et al., 2019; Challco et al., 2019) created gamification ontologies for different domains such as software engineering, lifecycle management, and learning.
However, to the best of the researchers' knowledge, there are no standardized approaches to the systemic use of gamification design knowledge that help guide design decisions in personalized gamified learning systems. Thus, to address this issue they have developed a gamification ontology that organizes and adequately links the concepts and knowledge related to personalized gamified learning systems design. SPARQL queries were developed to demonstrate the benefits of their ontology implementation (Horridge et al., 2011).

Finally, the resaechers adopt an existing gamified learning framework via enriching it with tools and mechanisms that aid software engineers in developing gamified e-learning systems that utilize the unexplored game elements in a personalized manner based on users' types, learning styles, and tasks nature.
The rest of this paper is structured as follows: Section 2 provides a brief background on the big five personality traits, player types, and learning styles. In addition to a summary of the state-of-the-art research of the field.

Section 3 summarizes the analysis of the unexplored elements. Section 4 shows the adopted research methodologies. Section 5 presents the participatory design study principles for unexplored gamification elements in gamified learning systems and the results reached. Section 6 shows the ontology IMPLEMENTATION. Section 7 provides the gamified e-learning framework. Finally, the last section presents the conclusion.

2. LITERATURE REVIEW

In this section, a discussion of the research work along with the foundation concepts related to our scope is presented.

2.1 Gamification and Learning

Gamification is a technique that encourages student participation using different activities and incentives (Tondello et al., 2016). Profoundly embedded in the motivational paradigm of active education, gamification is an innovative educational approach that systematically utilizes the different elements and features of gaming culture (Laine and Lindberg, 2020). Gamification examples include: playing educational games to learn new academic skills, gaining points for completing given

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activities or competing with peers to achieve a particular goal (Ibanez et al., 2014; Ofosu-Ampong and Boateng, 2018). Several researchers have been conducted on how to incorporate gamification in the education context. In Khaleel et al. (2016) and Lavoué et al. (2018), it was found that points, badges, and leaderboards are extremely powerful motivators that help students feel rewarded for their efforts and keep track of their progress, and encourage persistence. Also, challenges help students to stay motivated in the process of learning (Antonaci et al., 2019). Moreover, progress bars, avatars, and dashboards are a few examples of elements that improve the skills of gaming and learning (Ibanez et al., 2014; Akgün and Topal, 2018).

Interestingly, Alsawaier (2018) and Çakıroğlu et al. (2017) demonstrated that gamification elements and dynamics provide a positive motivational impact on students' engagement and academic performance. However, both of them mentioned that more longitudinal studies are needed on gamification in addition to mixed-method designs to help understand the relationship between gamification, engagement, and motivation. Unfortunately, most gamification in education studies focuses only on a few elements and neglect the main purpose of gamification in education, which is aiding students to immerse and effectively collaborate in the specified course or lecture. It was discussed in several studies that only BPL (badges, points, and leaderboards) were used and the other elements which are directly mapped to most of the personalities were ignored (Konert et al., 2013; Khaleel et al., 2016; Tondello et al., 2016; Akgün and Topal, 2018; Alsawaier, 2018; Ofosu-Ampong and Boateng, 2018).

2.2 User Types and Gamified Learning

It is now commonly accepted that personality characteristics have a major effect on academic achievement (Dicheva et al., 2015). Several studies have suggested the need for personalizing gamified systems according to users' personalities (Tondello et al., 2016). Personality trait theories have long sought to nail down how many personality types exist. Big Five Personality Traits are the most used model of personality in academic psychology. Those five personality traits are abbreviated as OCEAN (Pornsakulvanich et al., 2012; Tondello et al., 2016), which are: Openness: known as curious and open to new ideas; Conscientiousness: known as organized and systematic; Extraversion: known as being outgoing and enjoying social situations; Agreeableness: known as being tolerant and trusting; Neuroticism: known as being anxious and moody. Furthermore, Marczewski proposed six user types called "Gamification User Hexad" that have different motivations whether intrinsic or extrinsic in addition to their mechanics and dynamics (Marczewski, 2015). There are six player types that have different motivations and understanding, and their corresponding gamification techniques have a great effect on the design (Tondello et al., 2016).

Gamification User Types Hexad framework classifies users as follows: Philanthropists who are altruistic and willing to give without expecting a reward (Knutas et al., 2019); Socializers who want to interact with others and create social connections (Tondello et al., 2016); Achievers who seek to progress within a system by completing tasks, or prove themselves by tackling difficult challenges (Tondello et al., 2016); and Free Spirits who are motivated by the freedom to express themselves (Knutas et al., 2019). They like to create and explore within a system; Players will do whatever to earn a reward within a system, independently of the type of the activity (Tondello et al., 2019); Disruptors tend to disrupt the system either directly or through others to force negative or positive changes (Tondello et al., 2019). Adding to them General and Rewards Schedule are the eight main categories of the 52 gamification elements while each main category has a couple of sub-categories (Marczewski, 2015).

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The word "learning styles" refers to the understanding that each student learns in a unique way (Felder and Spurlin, 2005). An individual's learning style refers to the preferred way in which the student receives, processes, recognizes and preserves knowledge for further use (Pornsakulvanich et al., 2012). It is crucial for educators to consider the differences in the learning styles of their students so that they can incorporate best practices in their day-to-day tasks, curriculum, and assessments (Knutas et al., 2019).

Felder Learning Styles (FLS) are divided into four different dimensions and eight different learning styles which are (Felder and Spurlin, 2005; Pornsakulvanich et al., 2012; Zaric et al., 2017): Sensing learners: like to observe facts, gather data, concrete examples, strict information, and prefer to solve the problem via standard methods but they prefer practical tasks; Intuitive learners: prefer theories, concepts, dislike repetition, and prefer conceptual issues. They are innovative; Visual learners: prefer visual information such as diagrams, pictures, videos, graphs, and flowcharts and prefer questions with visual elements. They remember what they see clearly; Verbal learners: they like written, textual documents, books, lectures, spoken explanations and prefer Essay questions. They remember best what they hear; Active learners: enjoy practical assignments and experimentation to try things out. In addition, they like concrete examples, case studies, working in groups, and dislike being passive; Reflective learners: prefer to spend time examining and thinking through information and presentations with topics to think about. They like to work alone but they like to give their opinion as well; and Sequential learners: learn through linear steps. Materials must be read in a specific order and tasks with multiple steps are preferred. They can work with partial or superficial information; Global learners: follow holistic thinking processes and create their own learning plan. They can connect difficult materials, conceptual solutions and synthesize information.

It has been established by several authors that the current era's key is personalization (Buckley and Doyle, 2017; Akgün and Topal, 2018; Tondello and Nacke, 2018; Knutas et al., 2019). Knowing the influence of individual features on gamification experience will inform the successful design of gamified learning strategies and enable them to be effectively incorporated into the learning environments (Tondello et al., 2019). In other words, each student needs to be educated and rewarded in a way that motivates especially him/her.

Zaric et al. (2017) presented a model that consists of gamification elements in e-learning, phases of development management of e-learning, and Felder-Silverman learning styles. A gamified e-learning course model was proposed with the base of learning styles for materials and curriculum with Moodle as the basis of the development (Zaric et al., 2017). In addition to the structuring of the teaching material based on the FLS model and assessments, some activities were not mentioned and personality traits were not put into consideration as well.

Rapeepisarn et al. (2008) (30) put into consideration different aspects in designing educational computer games like learning styles, learning activities with game genres for developing quality-learning experience in class. On the other hand, Prensky's Study used activities and learning techniques in educational computer games. For example, Practice and feedback; Learning by doing and learning from mistakes; Goal-oriented learning; Task-based; Role-playing; Coaching, and intelligent tutors. However, the researcher did not mention elements and how the model will be applied in real life.

Previous research (Ibanez et al., 2014) has demonstrated that game elements have a relationship with motivation and can be applied to different software systems. Game Development or Educational System Development courses "GaMDeF" is a guide

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rather than a definitive design that provides different insights into the relationship between game elements and motivation (Buckley et al., 2018). However, it is more suited for computer games implementations. Although they mentioned 16 elements, they also said that some of them are hard to be used and incompatible with the learning systems. Even though they focused on motivation and learning neither personalities nor learning styles were mentioned in Buckley et al. (2018).

2.3 Gamification and Ontology

Ontology is to put the knowledge of a specific domain and represent it in a way that different applications can use (García et al., 2017). The ontology introduces the categories, properties, relations between the concepts, data, and entities of one or many domains (Challco et al., 2019) to support the developed theoretical concepts with the possibility for automated reasoning.

In Bouzidi et al. (2019), seven sub-ontologies which are core gamification concepts, organizational concepts, psychological concepts, evaluation concepts, ethical concepts, risk concepts, and concepts related to the user were named OntoGamif (Ontology for the Gamification domain). They argue that gamification may fail because there is a gap in the understanding of its implementation and design. Rokia et.al provide a clear description of concepts in the gamification domain in OntoGamif (Bouzidi et al., 2019). For example, Identifying gamification goals and design elements; Providing a global picture of the gamification domain; Showing possible gamification risks; Clarifing gamification concepts; identifying the different dynamics and mechanics; Understanding employee behavior and personal goals; and Identifying main ethical issues.

Other domain-specific ontologies were developed. For example, according to Félix et.al, 2017 Software Engineering and software organizations need gamification to make the tasks more attractive and challenging to be fulfilled (García et al., 2017). A framework composed of an ontology GOAL (Gamification focused On Application Lifecycle Management) to integrate and support gamification into the organization. In García et al. (2017), a gamification ontology was created to encourage the use of gamification in software projects.

In the learning domain, Challco et.al created an ontology to support the gamification of Scripted Collaborative Learning (CL) scenarios in which the game elements are tailored for each situation (Challco et al., 2019). The ontology OntoGaCLeS supported knowledge about personalization, game design and their effect on students' learning and motivation. According to Challco et al. (2019), a study was made on undergraduate students. The results showed that participants in gamified sessions were more motivated than the ones in non-gamified sessions.
More work is still needed to produce a more integrated ontology implementation in gamified learning that incorporates: 1) personality aspect, such as Big five personality traits, 2) learning styles; 3) educational tasks, and 4) gamification elements in an integrated way.

3. ANALYSIS OF UNEXPLORED GAMIFICATION ELEMENTS

In this section, the researchers discuss and investigate the gamification elements examined and/or utilized in the learning systems in the literature. According to El-Shorbagy et al. (2020), 32 unexplored elements were discussed in less than 10 papers in the literature. The authors analyzed more than 200 papers to reach this result. Also, it was found that only six elements have more than 40 references in literature, only nine elements vary between 10 to 28 references, 14 elements vary

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between 1 to 9 references, and finally, 23 elements are never mentioned in any reference at all.

The elements are used only to motivate 1/5 of the world's personalities which means that the researchers are trying to thrust the rest of the population into one kind of interest (El-Shorbagy et al., 2020). They argue that this is one of the main reasons that gamification risks are emerging. Gamification has many factors to succeed but it must be used in the right way. By formulating mappings to inform better design in a way that ensures coverage for all user types in the learning context.
There is no direct mapping between the big five personality traits and game elements. However, there is a mapping between the big five personality traits and gamification player types (Tondello et al., 2016; Akgün and Topal, 2018). Also, there is a mapping between the gamification player types and the game elements (Tondello et al., 2019). Therefore, there exists an indirect mapping between the big five personality traits and game elements. Adding to that, there is no mapping between Felder Learning Styles (Felder and Spurlin, 2005) and gamification player types or elements. However, there is a mapping between the big five personality traits and Felder Learning Styles (Siddiquei and Khalid, 2018). Therefore, there exists an indirect mapping between Felder Learning Styles, gamification player types, and the game elements.

Thus, this section discusses the mapping between gamification player types and the big five personality traits in addition to learning styles (El-Shorbagy et al., 2020). The new combined mapping as shown in Figure 1 consists of three levels between gamification player types, big five personality traits (OCEAN), and learning styles which led the researchers to a conclusion that the world focuses only on one single personality type, which is "conscientiousness". Whether it is in a player mode or a learning mode this is the only person that will succeed easily as the whole system is designed to go with his/her abilities to learn and grow. Unfortunately, the systems are trying to force the rest of the types to succeed in a way that is hard for them to achieve mastery. For example, extroversion will only succeed because he/she is positively correlated with all learning styles not because it is just a fit. He/she will be able to learn as he can be intuitive/sensing, which is the main focus of conscientiousness but maybe he needs the other learning styles to get everything well organized in his brain. Nevertheless, if openness to experience is not able to receive some active/reflective ways of learning, it shall be very hard for him/her to succeed. This is just the way his/her brain works but the system does not put this into consideration.

For the purpose of this research, the results achieved in El-Shorbagy et al. (2020) will be used as input. The researchers will further explore the design and use of the identified unexplored game elements while considering more factors such as the tasks performed in the learning environment and the users' learning styles.

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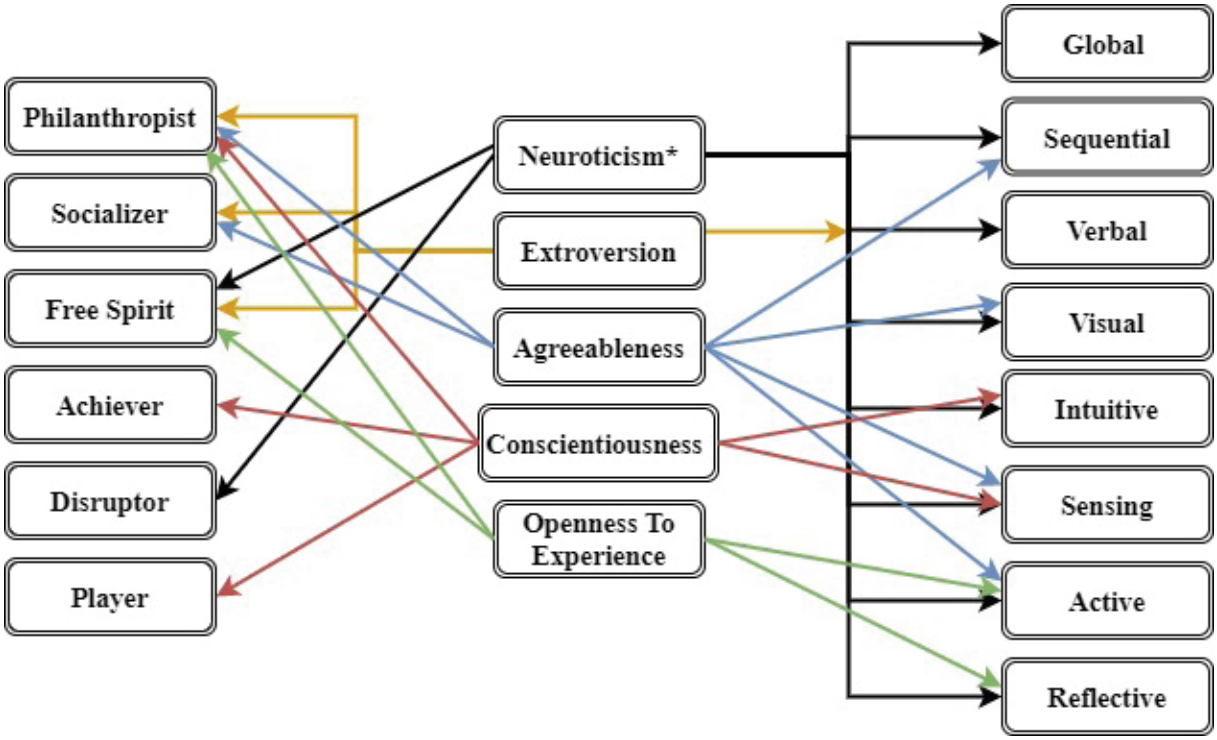

Fig. 1. Mappings between gamification player types, big five personality traits, and learning styles (El-Shorbagy et al., 2020).

4. RESEARCH METHODOLOGY

A qualitative approach (Lazar et al., 2017; Lune and Berg, 2017; Vaismoradi and Snelgrove, 2019) was chosen due to the exploratory nature of this research as more exploration was needed to gather insights from actual users to decrease the gap between students and learning and increase their motivation and long-term satisfaction and enjoy-ability. The main areas the researchers wanted to explore were:

- RQ1) From the users' perspective, what are their viewpoints and ideas regarding the utilization of unexplored game elements in gamified e-learning systems?
- RQ2) From the users' perspective, how can un-explored game elements be associated with the learning tasks?

Focus groups (Vaismoradi and Snelgrove, 2019) were used as a qualitative data collection method to investigate the unexplored elements that motivate the learning tasks while putting into consideration the personality traits and learning styles of users.

In the present study, the researchers recruited three participants for the pilot study and 15 participants for the actual full study as shown in Table 1. The focus groups were divided into two sessions, one contains eight participants and the second contains seven participants. All the sessions were video recorded and transliterated precisely to help in the analysis stage. Each session lasts for 120 minutes. For the review process of the current paper, the design of the study, the materials used in it, and samples of what the participants wrote or drafted, can be viewed on this link https://drive.google.com/drive/folders/1sQ_kQq_HOTg1l6RrSoOpy8F6J01iVIbV?usp=share_link.

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Table 1: Focus Group Sessions

Gender	Male	Female	Time Taken
Pilot study	0	3	150 minutes/each pilot
Focus group session # 1	6	2	120 minutes/session
Focus group session # 2	5	2	120 minutes/session
Total	11	7	690 minutes

The participants attended in a large university that has lots of branches in the Arab region and several dual programs with universities in the US and UK and ABET-accredited. In addition, it contains multiple nationalities and has wide variations in demographics. We have chosen participants that age between 18 and 24. All of the participants majored in computer science in their mid-high college years (2nd, 3rd, and 4th years) as they have more experience and can provide more value and insights.

In this study, the researchers choose two ready-made questionnaires for the recruitment of the participants to identify their personality traits and learning styles. They are the Big five-personality trait: BFI-S (15 questions) (Lang et al., 2011) and Felder Learning Styles: FLS questionnaire (44 questions) (Felder and Spurlin, 2005). Invitation emails were sent to the targeted participants with two links for the questionnaires. This step was made to ensure full coverage of all personality traits and learning styles in our study and the results are shown in Table 2. The rows represent the participants, the first five columns show the personality type results, while the last eight columns show the results of the learning styles.

Table 2: Heat Table of Personality Types and Learning Styles of Participatory Design Study

Open-ness	Conscien-tiousness	Extrover-sion	Agree-ableness	Neuroticism	Active	Reflec-tive	Sens-ing	Intuitive	Visual	Ver-bal	Sequen-tial	Glob-al
6	6	3.33	7	4.33	1	0	7	0	3	0	0	1
5.67	4.67	4.67	5.67	3.33	5	0	11	0	9	0	0	5
6	4.33	4.33	4.33	2.67	1	0	9	0	11	0	3	0
5.33	4.33	3.67	6.33	5.67	9	0	9	0	11	0	3	0
7	6	4.33	6	1.67	5	0	3	0	5	0	3	0
7	5.33	5.33	5.67	4.33	0	5	0	9	5	0	3	0
5.67	6.67	2.67	6	5	0	5	9	0	0	5	7	0
6.67	6.33	6.67	6	3.33	7	0	0	3	7	0	1	0
6	5.67	5	6.33	3.33	3	0	0	5	7	0	7	0
6	5.57	3.33	5.67	1	0	1	1	0	3	0	0	3
6.67	5.67	4	6.33	1	0	9	0	1	7	0	1	0
6.33	4.67	6	5.33	3.67	5	0	0	9	9	0	3	0
6.33	5.67	6	7	6.67	0	3	1	0	5	0	1	0
7	5.67	5	5.33	5	0	3	0	5	1	0	1	0
7	5.33	2.33	6	3.67	0	5	0	1	3	0	0	1

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Content analysis (Lazar et al., 2017; Vaismoradi and Snelgrove, 2019) was used to analyze the results of the focus group. It was the most suited technique to analyze the collected data in the current research. Finding the answer to who says what, to whom, with what effect, and the common patterns and characteristics of the document's content of this kind of research have uncovered new findings and concepts that evolved through conducting this study.

5. DESIGNING GAMIFIED LEARNING SYSTEMS –USERS' VIEWPOINT

In this section, the researchers explain the study that they have conducted with actual users to identify their point of view on the utilization of unexplored gamification elements in the learning context. In addition, they are building upon the results that they have reached from the analysis in (El-Shorbagy et al., 2020) that there are unexplored game elements in the learning context. Therefore, they have no prior hypothesis of the usage of such game elements in the design of gamified learning systems and that is why tthey explore this with actual users. First, they explain the study purpose and the pillars they build upon. Second, they explain the types of sessions that were conducted and their benefit and structure. Third, they elaborate on the supporting materials that were prepared and used during the study to help immerse the users to gain their in-depth opinions and feedback during the discussions. Then, they explain the reached results of the study. Finally, they discuss the threats to validity.

5.1 Purpose of the Study

According to the literature, many papers discussed the big five personality traits and game players (Tondello et al., 2016). While others showed the big five personality traits and learning styles (Pornsakulvanich et al., 2012). On the other hand, some mentioned learning styles with some tasks (Zaric et al., 2017). Finally, a few showed some game elements with some tasks (Rapeepisarn et al., 2008) as discussed in the literature.

However, in the present study the researchers combined four different pillars for exploring the design of gamified learning systems, which are: 1) Personality traits; 2) Learning styles; 3) Learning tasks; and 4) Unexplored game elements. As discussed, the personality trait is an important pillar that provides a simple scheme to know and understand users and their behavior. Also, identifying how a student learns best and accommodating to those requirements may have a significant impact on how he/she understands and interacts with the various topics being taught or required tasks. The researchers also argue that the task nature plays an important role in their choice of the suitable game element. Finally, they utilize in their study the identified unexplored game elements that can help enrich the learning domain and satisfy more user types.

Hence, the purpose of the current study can be summarized as follows:

1. To find a mapping between personality traits, learning styles, and game elements.
2. To discover the preferable game elements for the user types with learning styles in certain tasks.
3. To uncover the use of unexplored game elements in the learning context.
4. To provide guidance for software engineers to design personalized gamified learning systems.

5.2 Sessions Plan

In this section, the researchers explain the two session types used in the study, their aim, and structure, which are: 1) the pilot study and 2) focus group sessions.

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1) Pilot study

A pilot study was conducted with three participants to evaluate the feasibility of the study, provide training to the researcher conducting the focus groups, and determine whether the time required to finish the focus group is suitable. In addition, the participants were requested to provide comments to detect ambiguities and difficult questions, supporting material, immersion scenarios, presentation, and tasks. Furthermore, it aided in determining whether each question elicited an acceptable variety of replies. The goal was to ensure that responses could be translated in terms of the needed information and topics. This focus group was not analyzed and was not included in the study's findings.

Following this pilot study, measures were done to increase internal validity. The pilot research revealed two major concerns that needed to be addressed. First, some questions were removed due to duplication, and their ordering was changed due to confusion issues. Second, the supporting materials, specifically the immersion scenarios used to engage users, were rephrased to make them clearer and easier to understand.

2) Focus Group Sessions

Two focus groups were conducted with each of the recruited participants. Each session took about two hours of presentation and discussions. All the focus groups were voice and video recorded with consent from participants. Those records were then transcribed later to be used in the analysis.

Participants were involved in the focus groups through a participatory design approach. Participatory Design is a term used to describe creative activities done with end-users to explore their ideas about a tool, product, or service to guarantee that it fulfills their requirements and expectations. Thus, the end results are produced in collaboration with the intended audience, resulting in improved results and experiences, as the technique may provide clear insight into their terminology, priorities, and preferences.

The focus groups sessions were divided into four parts:

1. Breaking the ice and filling in demographical information.
2. A 10-15 min introductory presentation was given about gamification in general. The target of this step is to show the participants different platforms and make them understand gamification as a concept and how it can be used in various ways, especially in the learning context.
3. Understand the unexplored game elements: A slide was presented to explain each element with an example or scenario to make it clear for the participants which can be viewed on this link https://drive.google.com/drive/folders/1sQ_kQq_HOTg1l6RrSoOpy8F6J01iVIbV?usp=share_link.
4. Gather participants' opinions After explaining each element as participants were asked a group of questions. They were encouraged to discuss and brainstorm ideas on how each unexplored element can be utilized to motivate and engage in the learning tasks. Each participant had to make suggestions separately according to his/her opinion on which element best suits this task or how they can be used to enhance this task motivation, satisfaction, and enjoyability as shown in Figure 2.

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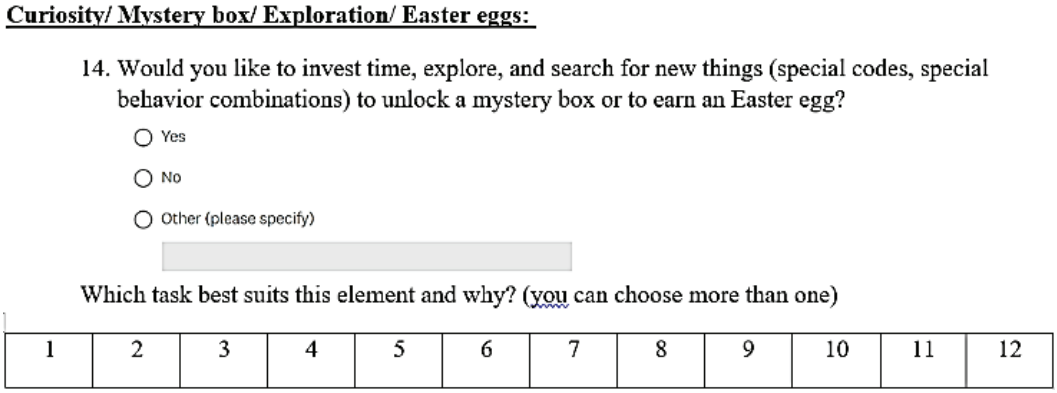

Curiosity/ Mystery box/ Exploration/ Easter eggs:

14. Would you like to invest time, explore, and search for new things (special codes, special behavior combinations) to unlock a mystery box or to earn an Easter egg?

- ○ Yes
- ○ No
- ○ Other (please specify)

Which task best suits this element and why? (you can choose more than one)

1	2	3	4	5	6	7	8	9	10	11	12

Fig. 2. A sample from the participatory design study questions

5.3 Supporting Materials

This section explains in detail the prepared supporting materials that were used during the study to present to participants and help them in the immersion and brainstorming to obtain in-depth insights and opinions. These materials were tested during the pilot study and enhanced according to participants' comments as mentioned in the previous section. All the supporting materials are shown on this link https://drive.google.com/drive/folders/1sQ_kQq_HOTg1l6RrSoOpy8F6J01iVIbV?usp=share_link.

1) Presentations

In the study, two presentations were presented to the participants shown in the shared drive. The first one was an introduction to gamification and learning in general. The second presentation contained a slide for each unexplored element with an example, mockup, real-life example, and/or scenario to make it clear for the participants so they can share their opinions and feedback on a well-based understanding of those elements.

2) Immersion Scenarios

Scenarios are described as "stories about people and/or their activities." Scenarios can be presented in a variety of ways, including text, storyboards, video mock-ups, written prototypes, and more. Instead of depending on the researcher's technical language, they enable imagining future work circumstances to allow people to experience how developing designs may impact work practice. Using scenarios in participatory design approaches enables context, needs, and requirements to be discussed. They may also be used as a means of communication amongst different stakeholders from various backgrounds throughout the session.

Thus, several specific scenarios designed for utilizing specific game elements were designed to immerse users and allow them to imagine their utilization and discuss opinions and enhancements. For example, in an element called Branching choices: Merging the eight different learning styles to create different branching choices for students not only to succeed but also to achieve excellence as shown in Figure 3. There might be more than a way to pass like choices between exams and projects. For example, if a student is Intuitive, he shall have a written exam from 80% and a practical exam from 20% while if he is Active, the practical exam shall be from 70% and written from 30% (Nelson, 2015; Day, 2017).

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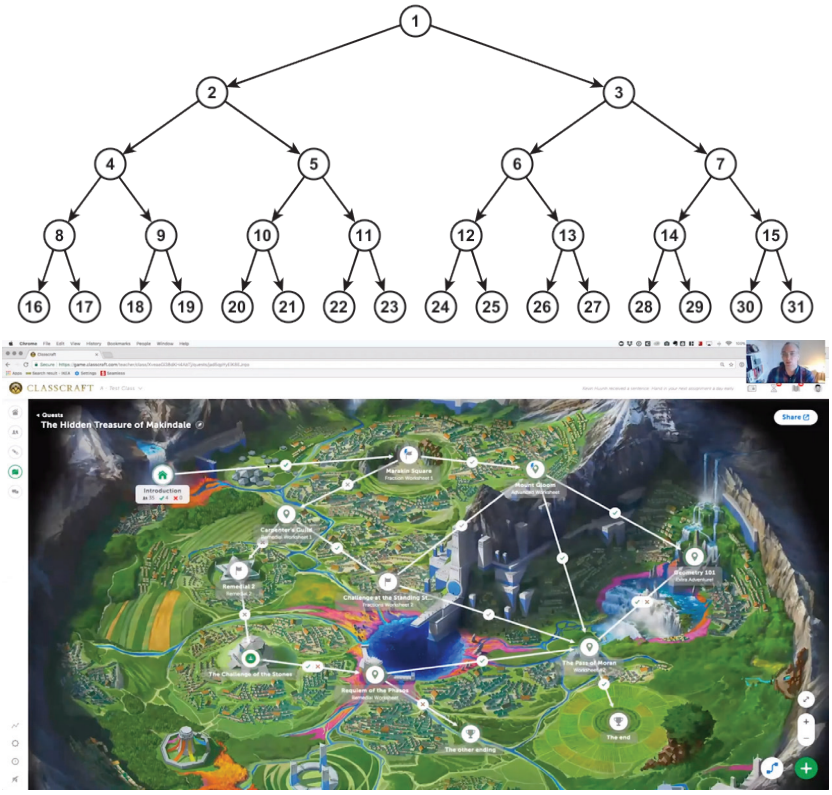

Fig. 3. Examples of branching choices in the immersion scenarios (Nelson, 2015; Day, 2017).

3) Tasks

The table of tasks was made with the inspirations of Zaric et al. (2017) and Rapeepisarn et al. (2008) as supporting material for the focus group session. In Zaric et al. (2017), the tasks shown concerning each learning style were based on the Felder and Silverman learning styles. They showed activities like Practical tasks, visual and essay questions, conceptual solutions, and issues. While in Rapeepisarn et al. (2008), Prensky's Study showed activities and learning techniques used in educational computer games. For example, feedback, Goal-oriented learning, Task-based learning, Coaching, and Intelligent tutors. Finally, in Rapeepisarn et al. (2008) there was Learning from mistakes because of different people's characteristics.

4) Questions and Activities

Each participant was given a set of questions. It was divided into three parts. Part 1 contained demographics and their opinion on studying and what can be improved. Part 2 contained general questions about gamification and learning. Finally, part 3 had questions related to unexplored elements, where for each unexplored game element, brainstorming and discussion took place. Then, each participant had to match the suitable learning task that can be motivated by this element from their opinion. Each participant had to suggest separately according to his/her opinion why this element best suits this task or how it can be used to enhance this task's motivation, satisfaction, and enjoy-ability.

Finally, they give their opinion on the scenario design and provide more ideas or examples on the tasks that are motivated by this element. A sample from the questions is shown in Figure 3 while the rest of the questions and tasks used exist in the shared folder in addition to some sample answers from the participants' responses.

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5.4 Study Results

In this section, the study results are described in detail. Depending on the participant's results, Table 3 was created as shown below to get the average of all personality types and learning styles to ensure full coverage of all learning styles and for each cross-section (Total of each learning style of this personality type/existing number of this personality type) to create Table 3. For the sake of the success of this study, the researchers have chosen a threshold of 2.25 that gives the full coverage for all learning styles by having at least one taken in a column. This criterion allowed the researchers to take moderate and strong learning styles values that affect the performance of the students as the mild data do not have a major effect on the students' performance, which means that the student with mild effect can do well in the two opposite learning styles like active-reflective or visual-verbal or sequential-global or sensor- Intuitive.

Table 3: Heat Table of Personality and Learning Styles Threshord

	Active	Reflective	Visual	Verbal	Sequential	Global	Sen-sor	Intui-tive
Neuroticism	4.5	1.5	8	0	2	0	5	0
Extroversion	6	0	8	0	2	0	0	6
Conscientiousness	0	5	0	5	7	0	9	0
Agreeableness	2.25	0.25	5.5	0	1.75	2.25	4.75	1.25
Openness	1	3.6	5.3	0	1.8	0.16	2	2.6

However, if a student is strong in visual, he/she will have problems or face difficulties with verbal intake. The results are put in a table format, where each table represents a single personality type. The top row represents the personality type, the second row shows the top-most learning styles related to this personality type according to the threshold taken in Table 3, and the results of the exams were presented in Table 2. While the left column shows the learning tasks. Finally, the cross-sections present the elements that motivate this task in addition to its matching learning style and personality trait.

5.4.1 Neuroticism personality type

In this study, the participants who were high in NEUROTICISM personality type in the focus group have relations with learning styles (Active, Visual and Sensor) based on the results of the BFI-S and FLS questionnaire. They preferred/choose the elements that shall increase their motivation for each of the 12 tasks in the learning context as shown in Table 4.

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Table 4: The Elements that Motivate Tasks with Neuroticism and Learning Styles

NEUROTICISM				
Tasks	Learning Styles	Active	Visual	Sensor
1	Practical assignments, experiments	√	√	√
			Development tools / Innovation platform / Social pressure /Fixed Rewards/ Random Rewards/ Time-Dependent Rewards	
		Learn/ New skills		
2	Student gives his opinion	√	√	√
		Anonymity/ Light touch / Branching choices / Social pressure / Fixed Rewards		
3	Question with visual elements	√	√	√
			Fixed Rewards/ Random Rewards/ Time-Dependent Rewards /Scarcity	
		Creativity tools		
4	Essay questions	√	√	√
			Virtual economy/ Access /Boss Battle /Social pressure/ Random Rewards/ Time-Dependent Rewards/ Strategy / Investment / Scarcity / Learn/ New skills	
		Fixed Rewards		
5	Task with multiple steps	√	√	√
			Curiosity/ Mystery box/ Exploration/ Easter eggs Fixed Rewards/ Random Rewards/ Time-Dependent Rewards	
		Boss Battle		
6	Conceptual solutions	√	√	√
			Development tools / Innovation platform / Social pressure / Fixed Rewards/ Random Rewards/ Time-Dependent Rewards	
		Curiosity/ Mystery box/ Exploration/ Easter eggs		
7	Practical tasks	√	√	√
			Social pressure /Fixed Rewards/ Random Rewards/ Time-Dependent Rewards / Learn/ New skills	
		Physical rewards / Certificate / Investment		
8	Conceptual issues		√	
			Boss Battle / Fixed Rewards/ Random Rewards/ Time-Dependent Rewards	
9	Tutoring others	√	√	√
			Development tools / Innovation platform / Social discovery / Social pressure / Social Status / Fixed Rewards/ Random Rewards/ Time-Dependent Rewards	
		Sharing knowledge / Care taking/ Gifting / Collect and Trade / Leaderboard and Social pressure / Signposting		
10	Class surveys	√	√	√
			Anonymity/ Light touch / Access / Social pressure / Fixed Rewards/ Random Rewards/ Time-Dependent Rewards	
		Branching choices		
11	Learn from mistakes	√	√	√
			Anonymity/ Light touch / Anarchy / Development tools / Innovation platform /Fixed Rewards/ Random Rewards/ Time-Dependent Rewards	
		Scarcity		
12	Gathering Data	√	√	√
			Development tools / Innovation platform / Social discovery / Social pressure / Fixed Rewards/ Random Rewards/ Time-Dependent Rewards / Signposting	
		Strategy		

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The most appropriate unexplored elements that motivate the learning tasks from the point of view of Neuroticism and their Learning styles are for example: In Virtual economy and Access he/she suggested tasks like essay questions, but why?
Conclusion: This person is visual, so he is having a hard time studying essay questions that is why he is trying to find a way to make himself more motivated to study those kinds of questions. Also, he/she wants access to those kinds of questions to help him/her with those kinds of questions that are hard for visual learners. But in practical tasks, they preferred physical rewards because they are related to real-life practices, and rewards will make students motivated as they gain more challenges.

While in anarchy participants suggested tasks were like learn from mistakes, but why?
Conclusion: This person wants an opportunity to learn from his/her mistakes without deduction in marks. He/she wants perfection in their work as well. They just want to know what is wrong to fix it and start over.

Sharing knowledge / Caretaking/ Gifting / Collect and Trade he/she suggested tasks, practical assignments, experiments, and practical tasks as he/she needs more help with those tasks from others. Social pressure: In this element, the conscientiousness personality type has chosen only one task for which the participant gives his opinion. This personality type always feels pressured by others' performance.
Conclusion: Here, the researchers can say that the more those tasks that have relation to others' performance increases the more this person's performance decreases. That is exactly why this person did not like to choose the leaderboard and social pressure at all.

5.4.2 Conscientiousness personality type

Participants who were high in the CONSCIENTIOUSNESS personality type in the focus group have relations with learning styles (Reflective, Verbal, Sequential and Sensor) based on the results of the BFI-S and FLS questionnaire. They preferred/chose the elements that shall increase their motivation for each of the following 12 tasks in the learning context as shown below in Table 5.

The most appropriate unexplored elements that motivate the learning tasks from the point of view of Conscientiousness and their learning styles are for example: In Access, he/she suggested tasks like conceptual solutions, but why?
Conclusion: This personality type has problems understanding conceptual solutions that is why he/she needs access from the question bank to fullfill his/her eagerness of knowledge to understand it well. That is why they mentioned it in Meaning / Purpose and they cannot figure out why they are taking this kind of task.
Sharing knowledge / Caretaking/ Gifting / Collect and Trade he/shesuggested Tasks like Practical assignments, experiments and Practical tasks as he/she needs more help with those tasks from others.

Social pressure: In this element CONSCIENTIOUSNESS personality type have, chosen only one task, which is Student gives his opinion. This personality type always feels pressured by others performance.
Conclusion: Here we can say the more those tasks that has relation to others performance increases the more this person performance decreases. That is exactly why this person did not like to choose the Leaderboard and Social pressure at all.

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Table 5: The Elements that Motivate Tasks with Conscientiousness and Learning Styles

CONSCIENTIOUSNESS					
Tasks	Learning Styles	Reflective	Verbal	Sequential	Sensor
1	Practical assignments, experiments	√	√	√	√
		Lottery / Meaning / Purpose / Sharing knowledge / Care taking/ Gifting / Collect and Trade / Boss Battle / Certificate Creativity tools / Fixed Rewards/ Random Rewards			
2	Student gives his opinion	√	√	√	√
		Social pressure			
3	Question with visual elements	√	√	√	√
		Scarcity			
4	Essay questions	√	√	√	√
		Boss Battle			
5	Task with multiple steps				
		N. A			
6	Conceptual solutions	√	√	√	√
		Meaning / Purpose / Access / Investment / Learn/ New skills			
7	Practical tasks	√	√	√	√
		Lottery / Sharing knowledge / Care taking/ Gifting / Collect and Trade / Boss Battle / Certificate / Creativity tools / Fixed Rewards/ Random Rewards			
8	Conceptual issues	√	√	√	√
		Creativity tools			
9	Tutoring others	√	√	√	√
		Physical rewards / Signposting / Strategy			
10	Class surveys	√	√	√	√
		Lottery / Anonymity/ Light touch			
11	Learn from mistakes	√	√	√	√
		Physical rewards			
12	Gathering Data	√	√	√	√
		Lottery / Anonymity/ Light touch			

5.4.3 Extroversion personality type

Participants who were high in EXTROVERSION personality type in the focus group have relations with learning styles (Active, Visual, & Intuitive) based on the results of the BFI-S and FLS questionnaire. They preferred/chose the elements that shall increase their motivation for each of the following 12 tasks in the learning context as shown below in Table 6.

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Table 6: The Elements that Motivate Tasks with Extroversion and Learning Styles

EXTROVERSION				
Tasks	Learning Styles	Active	Visual	Intuitive
1	Practical assignments, experiments	√	√	
		Physical rewards / Development tools / Innovation platform / Certificate / Curiosity/ Mystery box/ Exploration/ Easter eggs / Creativity tools / Fixed Rewards / Signposting / Strategy / Investment / Learn/ New skills		
2	Student gives his opinion	√	√	√
		Vote/ Voice / Certificate / Branching choices / Social Status / Fixed Rewards / Time-Dependent Rewards / Strategy /Investment		
		Creativity tools		
3	Question with visual elements	√	√	√
		Certificate / Random Rewards/ Investment / Learn/ New skills		
		Virtual economy /Development tools / Innovation platform /Curiosity/ Mystery box/ Exploration/ Easter eggs		
4	Essay questions	√	√	
		Physical rewards / Certificate/ Curiosity/ Mystery box/ Exploration/ Easter eggs/ Branching choices / Investment / Learn/ New skills / Consequences/ Loss Aversion		
5	Task with multiple steps	√	√	√
		Lottery / Development tools / Innovation platform / Certificate / Creativity tools / Learn/ New skills / Time-Dependent Rewards / Signposting / Strategy / Flow and Strategy / Investment / Consequences/ Loss Aversion		
		Meaning / Purpose		
6	Conceptual solutions	√	√	
		Lottery / Certificate / Creativity tools / Branching choices / Fixed Rewards / Strategy / Investment		
7	Practical tasks	√	√	√
		Development tools / Innovation platform / Creativity tools / Branching choices/ Investment / Learn/ New skills		
		Certificate / Consequences/ Loss Aversion		
8	Conceptual issues	√	√	
		Development tools / Innovation platform / Certificate / Creativity tools Fixed Rewards / Investment		
9	Tutoring others	√	√	√
		Lottery / Certificate / Social Status / Investment		
		Physical rewards / Development tools / Innovation platform		
10	Class surveys	√	√	√
		Certificate / Time-Dependent Rewards / Investment		
		Development tools / Innovation platform / Branching choices		
11	Learn from mistakes	√	√	√
		Physical rewards / Certificate / Social Status / Random Rewards / Investment / Scarcity		
		Lottery / Virtual economy		
12	Gathering Data	√	√	√
		Certificate / Curiosity/ Mystery box/ Exploration/ Easter eggs / Social Status / Time-Dependent Rewards / Investment		
		Branching choices		

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The most appropriate unexplored elements that motivate the learning tasks from the point of view of Extroversion and their learning styles are for example: If the student gives his opinion, he/she suggested tasks like creativity tools, but why?
Conclusion: This personality type likes outgoing and social interaction so they want various ways to show their opinion. While in task with multiple steps they mentioned meaning / purpose as they tend to be assertive because this personality wants to be sure of what is the purpose and why to take all the steps that will be taken out. Since this personality is gregarious, they like Tutoring others however they like to take the credit as well like physical rewards or to be a part of the development tools or innovation platform.

In practical assignments, experiments or tasks common elements were mentioned for the active and visual personalities like Development tools / Innovation platform / Creativity tools / Certificate / Investment / Learn/ New skills.
Conclusion: Here the researchers can say that those tasks that have a relation to teamwork and dealing with others to achieve and gain new information and leveling up.

5.4.4 Agreeableness personality type

Participants who were high in the AGREEABLENESS personality type in the focus group have relations with learning styles (Active, Visual, Global and Sensor) based on the results of the BFI-S and FLS questionnaire. They preferred/chose the elements that shall increase their motivation for each of the following 12 tasks in the learning context as shown below in Table 7.

The most appropriate unexplored elements that motivate the learning tasks from the point of view of Agreeableness and their learning styles are for example: In Investment, he/she suggested tasks like practical assignments, experiments, tasks, and learn from mistakes, but why?
Conclusion: This personality type is optimistic as they believe that by investing time, effort, emotions, or money, they will get value and gain from those tasks to evolve more.

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Table 7: The Elements that Motivate Tasks with Agreeableness and Learning Styles

AGREEABLENESS					
Learning Styles / Tasks		Active	Visual	Global	Sensor
1	Practical assignments, experiments	√	√	√	√
			Physical rewards /Virtual economy / Development tools / Innovation platform / Anarchy / Meaning / Purpose / Sharingknowledge / Care taking / Gifting / Collect and Trade / Learn / New skills / Fixed Rewards	Branching choices	Physical rewards / Learn / New skills
				Boss Battle	
			Access		
		Investment			
2	Student gives his opinion		√	√	
			Physical rewards / Anonymity / Light touch		
			Vote/ Voice		
3	Question with visual elements		√	√	√
			Vote/ Voice / Development tools / Innovation platform / Sharing knowledge / Care taking / Gifting / Collect and Trade / Learn / New skills / Curiosity / Mystery box / Exploration / Easter eggs	Creativity tools	Physical rewards
			Branching choices		
4	Essay questions	√	√	√	√
			Virtual economy / Anonymity/ Light touch / Development tools / Innovation platform / Anarchy / Time-Dependent Rewards	Lottery / Flow and Strategy	Physical rewards
			Access		
		Meaning / Purpose / Branching choices / Creativity tools			
5	Task with multiple steps	√	√	√	√
			Anonymity / Light touch / Certificate / Branching choices		Physical rewards / Learn / New skills
		Development tools / Innovation platform			
6	Conceptual solutions	√	√	√	√
				Curiosity / Mystery box / Exploration / Easter eggs	Learn/ New skills
		Meaning / Purpose			
7	Practical tasks	√	√	√	√
			Anonymity / Light touch / Certificate / Curiosity / Mystery box / Exploration / Easter eggs	Anarchy	Lottery / Virtual economy / Creativity tools
			Access		
			Learn/ New skills		
		Physical rewards / Development tools / Innovation platform / Boss Battle / Branching choices / Time-Dependent Rewards / Signposting / Investment			
8	Conceptual issues	√	√	√	√
			Certificate		Certificate
			Vote/ Voice / Curiosity / Mystery box/ Exploration/ Easter eggs		
		Anonymity / Light touch			

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Table 7: Cont.

AGREEABLENESS					
Learning Styles / Tasks		Active	Visual	Global	Sensor
9	Tutoring others	√	√	√	√
			Sharing knowledge / Care taking / Gifting / Collect and Trade / Learn/ New skills / Random Rewards	Vote/ Voice / Fixed Rewards	Physical rewards / Certificate
			Meaning / Purpose		
			Virtual economy		
		Creativity tools / Signposting			
10	Class surveys	√	√	√	√
			Anonymity / Light touch / Sharing knowledge / Care taking / Gifting / Collect and Trade	Certificate	Lottery
			Meaning / Purpose		
		Virtual economy / Fixed Rewards			
11	Learn from mistakes	√	√	√	√
			Anonymity / Light touch	Learn/ New skills / Signposting	
			Fixed Rewards		
		Investment			
12	Gathering Data		√	√	√
			Physical rewards / Virtual economy / Anonymity / Light touch	Learn / New skills / Investment	Physical rewards / Creativity tools
				Certificate	
			Meaning / Purpose		

5.4.5 Openness Personality type

Participants who were high in OPENNESS personality type in the focus group have relations with learning styles (Reflective, Visual and Intuitive) based on the results of the BFI-S and FLS questionnaire. They preferred/chose the elements that shall increase their motivation for each of the following 12 tasks in the learning context as shown below in Table 8.

The most appropriate unexplored elements that motivate the learning tasks from the point of view of Openness and their learning styles are for example: In Creativity tools, he/she suggested ten Tasks where it can be used like practical assignments, experiments, tasks, student gives his pinion, questions with visual elements, essay questions, conceptual solutions, tutoring others, class surveys, learn from mistakes, and gathering data, but why?
Conclusion: This personality type is Intelligent and Imaginary. They like to think out of the box so this element will give them a way to put their own fingerprint in the normal boring learning tasks. Even though only three tasks were related to visual-only like conceptual solutions, class surveys, and practical tasks, the rest was common for all learning styles.

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Table 8: The Elements that Motivate Tasks with Openness and Learning Styles

OPENNESS				
Learning Styles / Tasks		Reflective	Visual	Intuitive
1	Practical assignments, experiments	√	√	√
		Anonymity/ Light touch/ /Anarchy / Meaning / Purpose	Sharing knowledge / Care taking/ Gifting / Collect and Trade/ Certificate / Curiosity / Mystery box/ Exploration/ Easter eggs / Social pressure/ Leaderboard and Social pressure / Consequences/ Loss Aversion/ Signposting / Investment /Scarcity	
		Physical rewards / Development tools / Innovation platform / Access / / Flow and Strategy		
		Virtual economy /Anonymity/ Light touch / Boss Battle / Learn/ New skills / Creativity tools / Branching choices / Time-Dependent Rewards / Strategy / Social Status		
2	Student gives his opinion	√	√	√
			Curiosity/ Mystery box/ Exploration/ Easter eggs / Social pressure /Leaderboard and Social pressure / Fixed Rewards/ Consequences/ Loss Aversion / Strategy / Flow and Strategy	Anonymity/ Light touch / Social Status
		Physical rewards / Virtual economy		
			Development tools / Innovation platform / Boss Battle	
		Learn/ New skills		
		Access / Sharing knowledge / Care taking/ Gifting / Collect and Trade / Meaning / Purpose / Certificate / Creativity tools / Branching choices / Signposting / Investment		
3	Question with visual elements	√	√	√
		Sharing knowledge / Caretaking/ Gifting / Collect and Trade	Virtual economy / Meaning / Purpose / Social pressure / Leaderboard and Social pressure / Consequences/ Loss Aversion / Signposting / Strategy / Flow and Strategy / Investment/ Scarcity	
			Development tools / Innovation platform	
		Access / Learn/ New skills		
		Anonymity/ Light touch / Creativity tools / Branching choices / Social Status / Fixed Rewards		
4	Essay questions	√	√	√
		Sharing knowledge / Care taking/ Gifting / Collect and Trade / Boss Battle	Meaning / Purpose / Certificate / Social discovery / Social pressure/ Leaderboard and Social pressure / Consequences/ Loss Aversion / Signposting / Investment	Lottery / Anonymity/ Light touch / Development tools / Innovation platform
		Physical rewards / Virtual economy/ Access/ Learn/ New skills / Strategy		
		Creativity tools / Branching choices / Fixed Rewards		
5	Task with multiple steps	√	√	√
		Anonymity/ Light touch	Virtual economy/ Meaning / Purpose / Certificate / Social pressure / Leaderboard and Social pressure / Fixed Rewards/ Random Rewards/ Time-Dependent Rewards / Consequences/ Loss Aversion / Signposting / Strategy / Investment	Lottery /Physical rewards / Anonymity/ Light touch / Social discovery
		Development tools / Innovation platform / Access / Flow and Strategy		
		Learn/ New skills / Branching choices / Social Status / Scarcity		
6	Conceptual solutions	√	√	√
		Sharing knowledge / Caretaking/ Gifting / Collect and Trade	Virtual economy / Certificate / Creativity tools Fixed Rewards/ Time-Dependent Rewards / Consequences/ Loss Aversion/ Signposting / Strategy	Lottery / Anarchy / Social discovery
			Social pressure / Leaderboard and Social pressure	
		Anonymity/ Light touch / Access / Investment		
		Physical rewards / Development tools / Innovation platform / Learn/ New skills / Boss Battle / Curiosity/ Mystery box/ Exploration/ Easter eggs / Branching choices / Social Status / Random Rewards/ Scarcity		

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Table 8: Cont.

OPENNESS				
Learning Styles / Tasks		Reflective	Visual	Intuitive
7	Practical tasks	√	√	√
		Meaning / Purpose	Sharing knowledge / Care taking/ Gifting / Collect and Trade / Certificate / Creativity tools / Social discovery/ Social pressure / Consequences/ Loss Aversion / Signposting / Flow and Strategy / Investment	Anonymity/ Light touch
			Lottery / Leaderboard and Social pressure	
		Access		
		Physical rewards / Virtual economy / Development tools / Innovation platform / Learn/ New skills / Boss Battle / Curiosity/ Mystery box/ Exploration / Easter eggs / Branching choices / Social Status / Time-Dependent Rewards / Strategy/ Scarcity		
8	Conceptual issues	√	√	√
			Meaning / Purpose / Sharing knowledge / Care taking / Gifting / Collect and Trade / Boss Battle /Curiosity/ Mystery box/ Exploration / Easter eggs / Leaderboard and Social pressure / Fixed Rewards/ Random Rewards/ Time-Dependent Rewards / Consequences/ Loss Aversion / Signposting / Investment	Physical rewards
			Virtual economy /Social pressure / Scarcity	
		Anonymity/ Light touch / Access / Learn/ New skills / Strategy		
9	Tutoring others	√	√	√
		Anonymity/ Light touch	Lottery / Boss Battle / Certificate / Curiosity/ Mystery box/ Exploration / Easter eggs / Branching choices / Social pressure / Leaderboard and Social pressure / Fixed Rewards/ Random Rewards /Time-Dependent Rewards / Consequences/ Loss Aversion / Signposting / Investment	Anonymity/ Light touch / Anarchy/ Social discovery /
			Flow and Strategy	
		Access / Learn/ New skills		
		Virtual economy / Development tools / Innovation platform/ Sharing knowledge / Care taking/ Gifting / Collect and Trade / Creativity tools / Strategy		
10	Class surveys	√	√	√
		Meaning / Purpose	Vote/ Voice / Development tools / Innovation platform / Anarchy / Boss Battle / Curiosity/ Mystery box/ Exploration/ Easter eggs / Creativity tools/ Branching choices / Social discovery / Social pressure / Leaderboard and Social pressure / Consequences/ Loss Aversion / Signposting Flow and Strategy / Scarcity	Anonymity/ Light touch / Investment
		Access / Learn/ New skills / Strategy		
		Virtual economy / Fixed Rewards/ Random Rewards/ Time-Dependent Rewards		
11	Learn from mistakes	√	√	√
		Investment	Certificate / Curiosity/ Mystery box/ Exploration/ Easter eggs / Branching choices / Social discovery / Leaderboard and Social pressure / Fixed Rewards/ Random Rewards/ Time-Dependent Rewards / Signposting / Flow and Strategy	Anonymity/ Light touch
			Virtual economy / Social pressure / Consequences/ Loss Aversion	
		Learn/ New skills		
		Physical rewards / Access / Development tools / Innovation platform / Access / Boss Battle / Creativity tools / Social Status / Strategy / Scarcity		
12	Gathering Data	√	√	√
		Anarchy / Meaning / Purpose / Investment	Leaderboard and Social pressure / Consequences / Loss Aversion	Anarchy
			Certificate / Signposting	
		Anonymity / Light touch / Flow and Strategy		
		Physical rewards /Virtual economy / Development tools / Innovation platform / Access /Sharing knowledge / Care taking/ Gifting / Collect and Trade / Learn/ New skills /Boss Battle / Curiosity/ Mystery box/ Exploration/ Easter eggs / Creativity tools / Branching choices / Social Status / Fixed Rewards/ Random Rewards/ Time-Dependent Rewards / Strategy / Scarcity		

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5.4.6 Threats to Validity

There are three main threats to validity in this study:

1. The participants were given scenarios for the unexplored elements that contained examples of detail of usage in the learning system. This could have influenced the quality of the participants' responses, especially in the area regarding giving more ideas. To minimize this effect, the study moderator constantly advised the participants to think out of the box and generate their ideas. Besides, the moderator always gave the pros and cons of the scenario to motivate participants to share their opinions and evolve with new ideas as reached in the final version.
2. One of the threats was the risk of 'group think' and the group dominators in the focus group. That was put into consideration, the study moderator always encouraged them to provide their opinions in addition to the use of supporting materials and documents. With the questions to be filled all participants were able to give their opinions and there were no passive participants.
3. A common threat to validity in focus groups studies is whether all the participants understood the questions as intended. This issue was addressed by explaining and exemplifying each question with a slide in a presentation. Also, all questions went through a pilot study and iterative revisions with two research members to ensure clarity.

6. ONTOLOGY IMPLEMENTATION OF GAMIFIED LEARNING

In this section, the design of the structure of the ontology is explained. The ontology will serve as a model of gamification in learning environments, and a guideline for the design of the gamified learning environment for software engineers (Horridge et al., 2011). The ontology will help software engineers to fill this gap of gamification with clear guidelines developed from a previous research (El-Shorbagy et al., 2020) and the focus group study. Previous research papers on gamification and ontology usually presented the most used and well-explored game elements.
However, the proposed ontology provides 4-dimension aspects (personality, learning style, tasks, and elements) in the same study as shown in Figure 4.

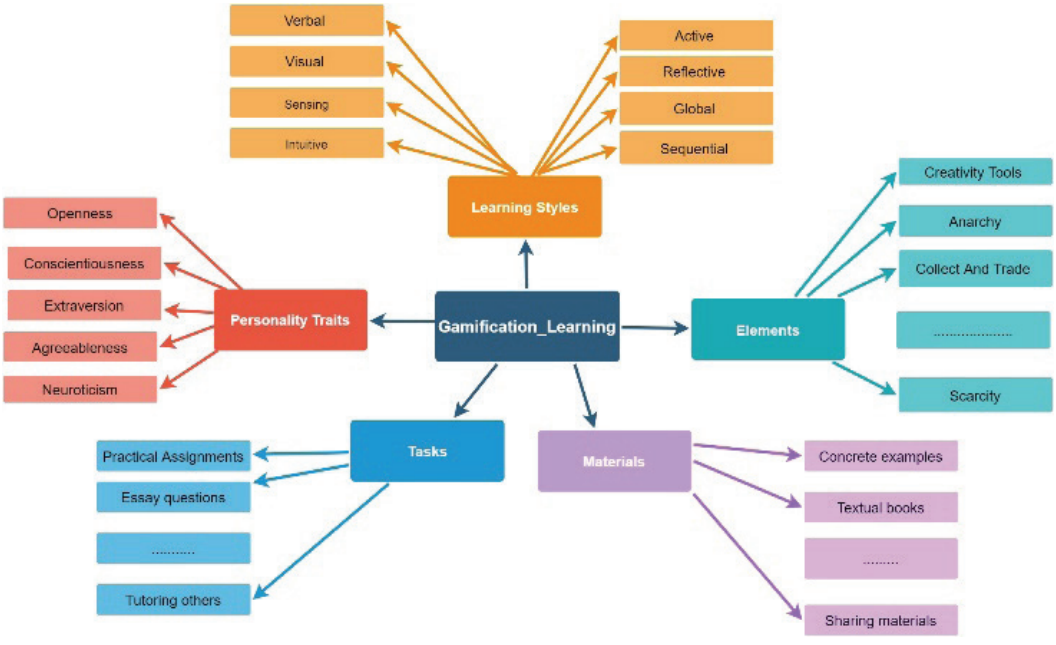

Fig. 4. The main five classes of Gamification learning ontology

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6.1 Class Hierarchy

Figure 5 shows the main class Learning_Gamification and the five main subclasses derived from it in the ontology. Learning_Gamification is used to define a new structure for gamification in learning that was devised from the participatory design study. This structure combines several new dimensions that the engineers will use to enhance the current gamified learning apps.

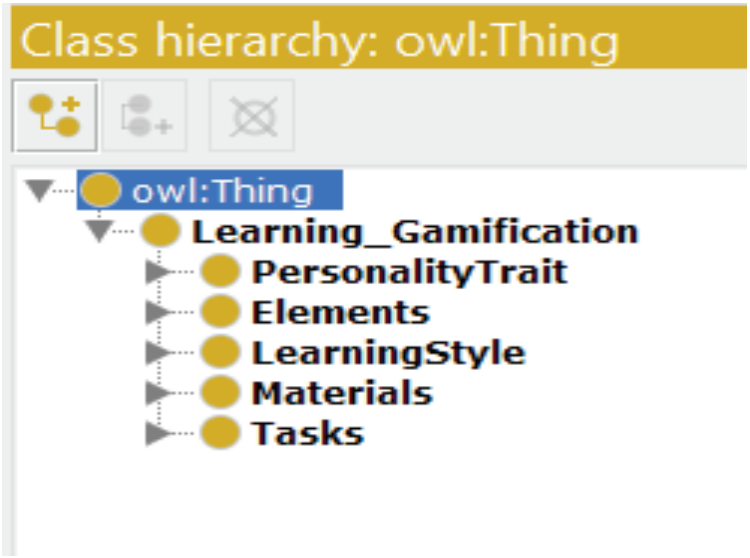

Fig. 5. A collapsed view of the implemented Ontology Class Hierarchy.

There are five sections, which are PersonalityTrait, Elements, LearningStyle, Materials, and Tasks as shown in Figure 5. Also, each main class has a group of sub-classes as provided in Figure 6. For example, the main class Materials have sub classes like (Attendance, Research, …).

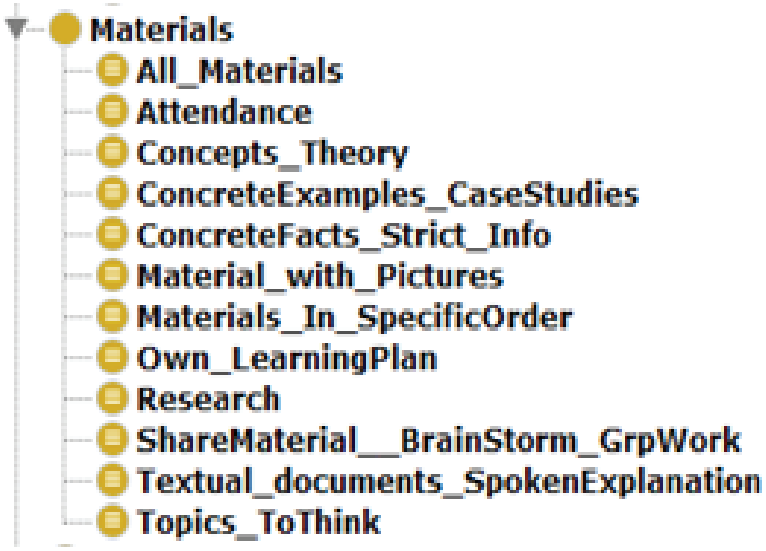

Fig. 6. A detailed view for the "Materials Types" class

6.2 Object Properties

The classes will not be sufficient in providing information. A collection of object properties, in addition to the taxonomy, was created to explain the relationship between the classes and is used to construct the rules that regulate the constitution of each class and is shown in Figure 7. These relations and rules reflect the results reached from the focus group study that was conducted and explained in the previous section. They are also helpful joins for query processing.

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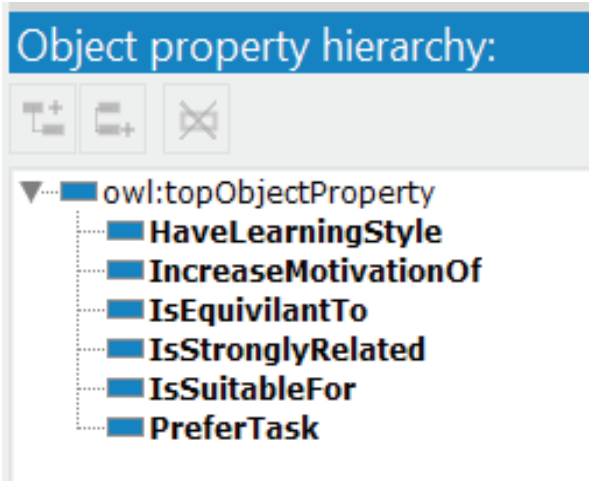

Fig. 7. A detailed view for the object properties

According to Horridge et al. (2011), "Web Ontology Language (OWL) Properties represent relationships between two classes. Properties may have a domain and a range specified. Properties link classes from the domain to classes from the range". The OWL domains and ranges are used as 'axioms' in reasoning, not constraints as shown in Table 9.
For example:

1. Each domain "PersonalityTrait" has object property "HaveLearningStyle" and range "LearningStyle". It means that any personality type may have more than one learning style. Ex. Neuroticism has active, sensor, and visual learning styles.
2. Each domain "Elements" have object property "IsSuitableFor" and range "Tasks". It means that any Element may be suitable for more than one Task. Ex. Certificate element is suitable for tasks like practical tasks and practical experiments.
3. Each domain "Elements" has object property "IncreaseMotivationOf" and range "PersonalityTrait". It means that any Element may have more than one personality type that increases its motivation. Ex. Element Fixed Reward Schedule increase motivation of Neuroticism personality trait.

Table 9: Object Properties' Domain and Range

Object Property	Domain	Range
IsEquivilantTo	All_Materials	Materials
HaveLearingStyle	PersonalityTrait	LearningStyle
IncreaseMotivationOf	Elements	PersonalityTrait
IsStronglyRelated	Tasks	Materials
IsSuitableFor	Elements	Tasks
PreferTask	LearningStyle	Tasks

6.3 Class Rules

After describing the class and object property hierarchies, this section demonstrates how to use them to define the rules that govern class usage.
For example, the element Creativity_Tools increases the motivation of personality trait Neuroticism, which has learning styles active, sensor, visual, and prefer tasks like visual questions. On the other hand, the same element Creativity_Tools increases the motivation of the personality trait Conscientiousness, which has learning styles

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reflective, sensor, sequential, verbal, and prefer tasks like conceptual issues, practical experiments, and practical tasks with this element that is shown in Figure 8.

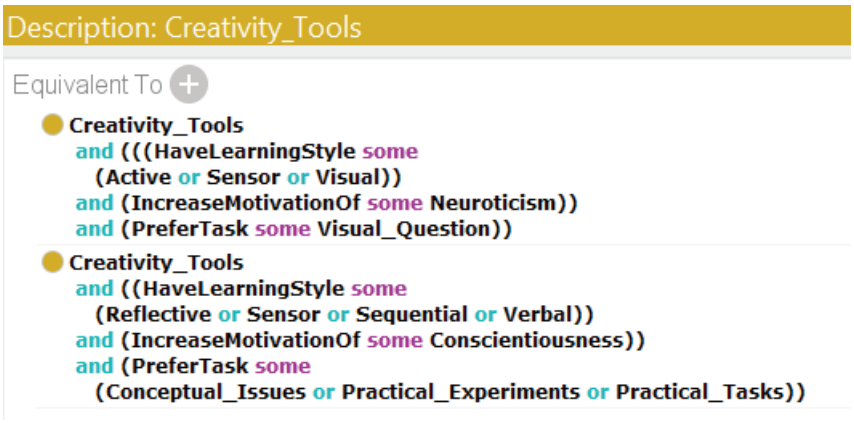

Fig. 8. The rule description for one of the elements "Fixed Rewards"

That illustrates that elements can motivate different personalities but learning styles and tasks must be put into consideration to provide the best results.

6.4 Sample Instances

In this section, an example of a scenario implementation is explained through a running case. First, some of the instances of the ontology are shown in Figure 9.

Fig. 9. An illustration of some instances of ontology

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While in Figure 10, Sensor_C that is related to consciousness is described using tasks that this learning style prefers and which are the mandatory components for providing this learning style specification that conforms to the rule defined by the ontology.

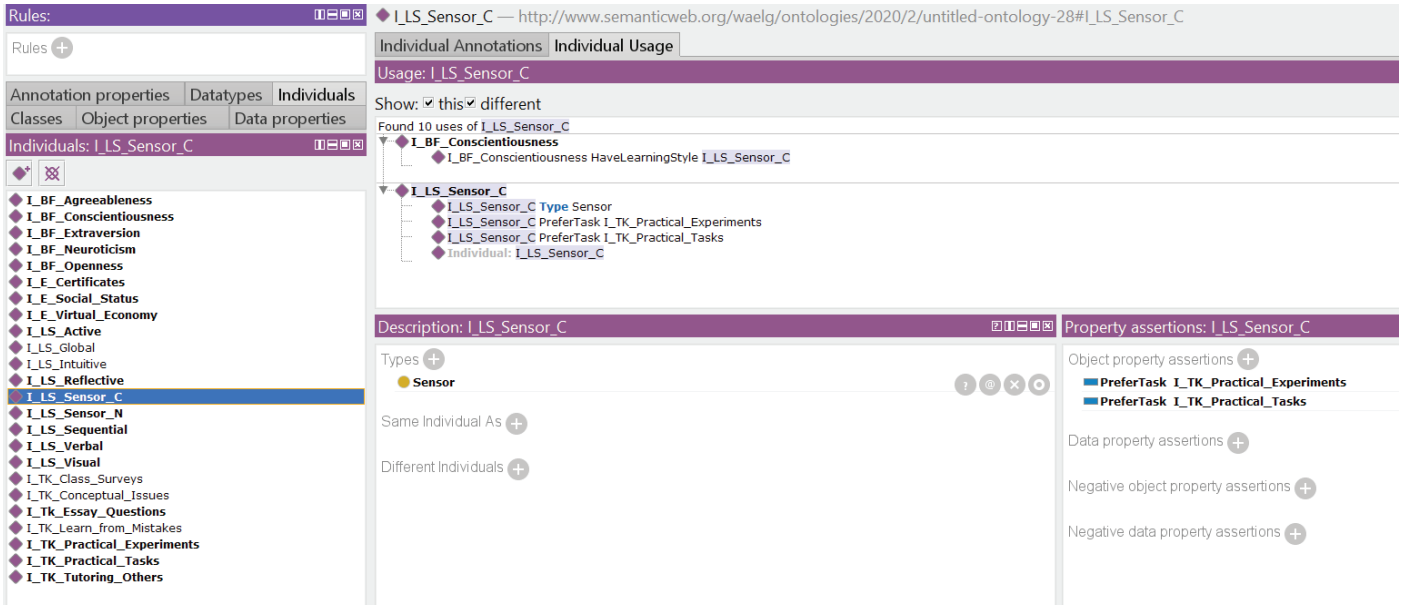

Fig. 10. Sensor learning style and its object property assertions

On the other hand, Figure 11 illustrates the graph representation of a personality type instances neuroticism and their relations with some classes, showing distinct coloring for the different object properties used.

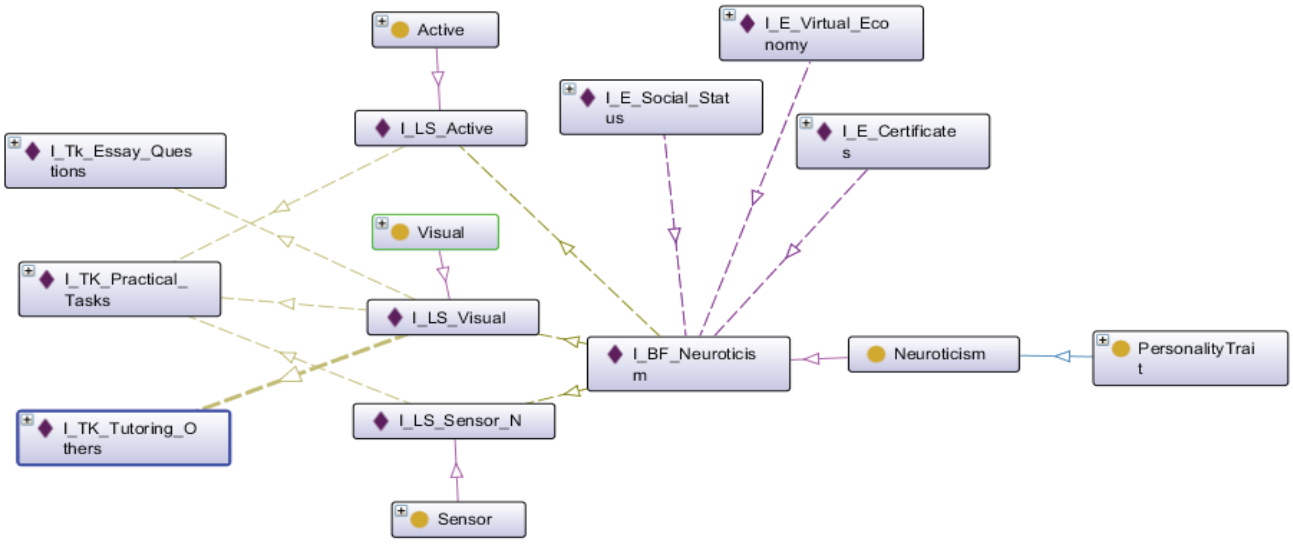

Fig. 11. A graph representation of Neuroticism personality type

Finally, Figure 12 illustrates a query and sample output for the personality traits and learning styles that were implemented using SPARQL Query Language to extract information from instances. The query asked for the personality trait and the learning style and a sample of the output is shown under the query that shows conscientiousness and its learning styles and neuroticism and its learning styles.

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In the current research, the ontology acts as the rule engine component for utilizing the four dimensions of the focus group study (personality, learning style, tasks, and elements) to be used. It is a way to formalize the guidelines adopted from the study so that the engineers can use them easily. Finally, providing an ontology design that firmly stands by the study results and design rules offers validation on how well the ontology accomplishes its anticipated tasks. The ontology file is shared on the drive in this link https://drive.google.com/drive/folders/1sQ_kQq_HOTg1l6RrSoOpy8F6J01iVIbV?usp=share_link.

Snap SPARQL Query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX OL: <http://www.semanticweb.org/waelg/ontologies/2020/2/untitled-ontology-28#>

SELECT distinct  ?BF ?LS
WHERE
{
        {?E OL:IncreaseMotivationOf ?BF}
        {?BF OL:HaveLearningStyle ?LS}
        {?LS OL:PreferTask ?T}
        {?E OL:IsSuitableFor ?T}
}
ORDER BY  ?E ?BF ?LS ?T
```

Execute

?BF	?LS
OL:I_BF_Conscientiousness	OL:I_LS_Reflective
OL:I_BF_Conscientiousness	OL:I_LS_Sensor_C
OL:I_BF_Conscientiousness	OL:I_LS_Sequential
OL:I_BF_Conscientiousness	OL:I_LS_Verbal
OL:I_BF_Neuroticism	OL:I_LS_Active
OL:I_BF_Neuroticism	OL:I_LS_Sensor_N
OL:I_BF_Neuroticism	OL:I_LS_Visual

Fig. 12. A SPARQL Query example for extracting information.

7. THE GAMIFIED E-LEARNING FRAMEWORK

A final contribution to the literature is supporting the research outcomes with an enhanced framework for gamification in learning as illustrated in Figure 13.
This engineering framework provides a standard way for engineers to design gamified learning systems. This framework shows the basic components and the relationships between them.

It incorporates management of user types, gamification in learning, courses, management of learning system, and the ontology models used to store, retrieve, and reuse information. Also, it provides a view of the dependencies between them. Finally, it shows the new artifacts that were developed and presented in this paper that are highlighted in yellow.

The framework presented in Figure 13 is based on the previous framework proposed in (Zaric et al. (2017). It provides augmented components used to enhance the model according to the focus group study that was conducted.

According to Zaric et al. (2017) gamified courses should increase student motivation, engagement, and provide an atmosphere in which students are proactive, motivated,

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and express a positive attitude toward learning. However, the researchers believe that more dimensions should be considered to enhance students' experience and that is why the big five-personality trait as a questionnaire and a component is added to the framework in the management of user types. The management of the Big five personality traits is beside the management of Learning styles that contain the FLS questionnaire in addition to the unexplored elements (unexplored game mechanics and unexplored game dynamics) that are studied in depth in the focus group study. They are added to the gamification of the learning block to help software engineers focus on the unexplored elements that are important for many users in learning applications.

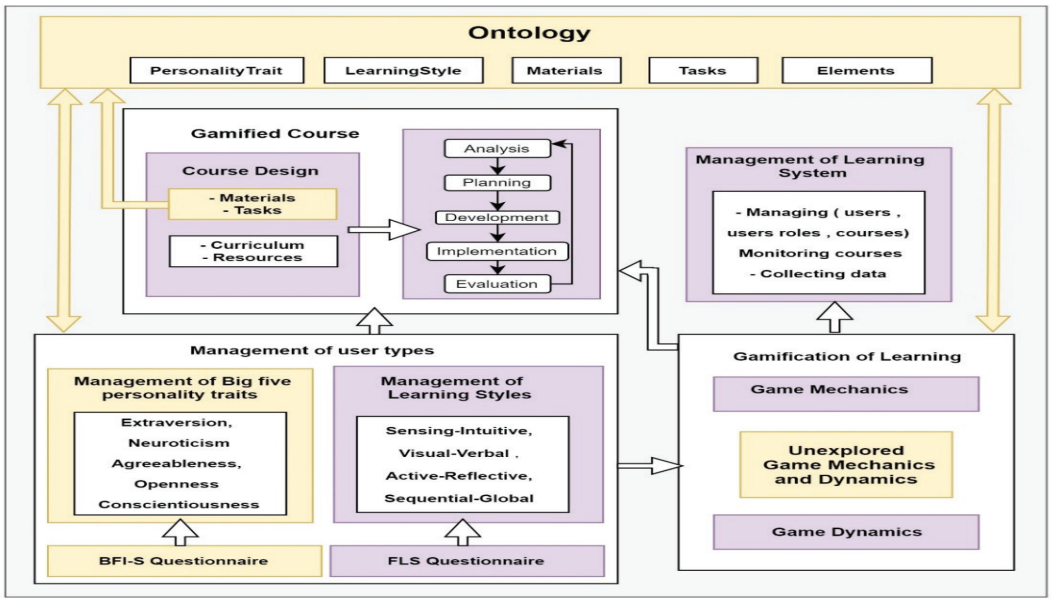

Fig. 13. Model of gamification in learning based on big five personality traits, students learning style, unexplored elements, and ontology

Adding to that more tasks and materials mentioned in Rapeepisarn et al. (2008) are added to the framework because they were not mentioned by Nadja et.al. The tasks and materials components are added to the course design block to be taken into consideration while the software engineer is designing the learning application. The yellow arrow coming out from materials and tasks components is fed into the ontology depending on each course design. On the other hand, the two yellow arrows coming from the management of user types and gamification of learning blocks are bidirectional arrows. They are used to guide system designers on how to apply a personalized system that adapts the gamification elements based on user types and learning styles in the tasks of the different courses. Personality traits, learning styles, material, tasks, and elements are added to the ontology in addition to their mapping that is reached through the researchers' study as shown in Figure 13 and many components are fed to the ontology for validation.

The researchers believe that this framework shall guide software engineers in their future designs to create more usable personalized systems where users could benefit the most from them and achieve mastery as well in learning and, in addition, to detect the users who are not put into consideration in the platform or system. In learning, this will help give more attention to the students that are either losing performance, demotivated, or having a decline in their system loyalty. In the researchers' opinion, merging all those factors shall reduce gamification risks and switch gamification to excel in the new era.

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8. CONCLUSION

This paper focused on experimenting with unexplored gamification elements in addition, to the mappings between Player types, Big Five personality traits, and learning styles that showed the partially and neglected users in the gamified learning context. The researchers' findings shall redirect researchers, software engineers, and lecturers to focus more on alternative ways in teaching or in designing apps in different ways to give more opportunities for all types of users to enhance long-term motivation. Furthermore, providing individualized instructions is not the goal of teaching and learning but a more balanced personalized way shall maximize their learning.

In addition, the second part of this paper focused on an in-depth focus group study and its supporting materials, that helped in reaching a new conclusion regarding applying game elements in learning. This study looked at the learning system from four different dimensions to cover the vital factors to enable all students regardless of their differences whether it is personality or learning style to achieve better in academic and learning systems.

The resulting detailed user profiles provide detailed guidelines to software engineers when designing gamified learning systems using the elements that were explored in our study. Also, implementing these results through an ontology will help software engineers in extracting important knowledge using automated means during the development of learning systems.

The final contribution to the literature is the enhanced gamified e-learning framework. This engineering framework provides a standard way for software engineers to analyze, design, and implement personalized gamified learning systems. This framework shows the basic and added components and the relationships between them. It also incorporates the new ontology model used to store and retrieve information.

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